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Eastern Environmental
Radiation Facility
P. O. Box 3009
Montgomery, AL 36193

EPA 520/5-84-012
June 1984

Radiation

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An Airborne Radioactive Effluent Study at the Savannah River Plant

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AN AIRBORNE RADIOACTIVE EFFLUENT STUDY
AT THE SAVANNAH RIVER PLANT

July 1984

U.S. Environmental Protection Agency
Office of Radiation Programs

MASTER

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December 1984

The following errata apply to the document entitled An Airborne Radioactive Effluent Study at the Savannah River Plant (EPA 520/5-84-012, June 1984).

ERRATA

Page	For	Read
~~4, Table 1.1~~	Gases and Vapors [above line]*	Gases and Vapors [below line]
5, line 9	amounts Kr-85	amounts are Kr-85
8, line 22	food	food (as shown in Table 1.4)
9, Table 1.4	(Cs-134/137	(Cs-134/137)
15, line 14	information an annual estimate of	information,
28, line 22	correlations	concentrations
37, line 23	the four	the sets of four
51, line 18	were	was
59, line 17	Tables 4.2 and 4.4	Table 4.2
83, line 10	Table 4.3	Table 4.4

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*Brackets in these errata enclose editor's notes.

FOREWORD

Under the Clean Air Act, Sections 112 and 122 as amended in 1977, the Office of Radiation Programs (ORP) of the United States Environmental Protection Agency is currently developing standards for radionuclides emitted to the air by several source categories. In order to confirm source-term measurements and pathway calculations for radiation exposures to humans offsite, the ORP performs field studies at selected facilities that emit radionuclides. This report describes the field study conducted at the Savannah River Plant (SRP), a laboratory operated by E.I. du Pont de Nemours and Company for the U.S. Department of Energy.

The purpose of the study at SRP was to verify reported airborne releases and resulting radiation doses from the facility. Measurements of radionuclide releases for brief periods were compared with measurements performed by SRP staff on split samples and with annual average releases reported by SRP for the same facilities. The dispersion model used by SRP staff to calculate radiation doses offsite was tested by brief environmental radioactivity measurements performed simultaneously with the release measurements, and by examining radioactivity levels in environmental samples.

This report describes in detail all measurements made and data collected during the field study and presents the results obtained. Readers of this report are encouraged to submit any comments or suggestions they might have. Requests for further information are also invited, and should be addressed to the Environmental Protection Agency, Office of Radiation Programs, Washington, DC, 20460.

Glen L. Sjoblom

Glen L. Sjoblom, Director
Office of Radiation Programs

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1. INTRODUCTION

1.1 Purpose of Study

Under the Clean Air Act, Section 112, the U.S. Environmental Protection Agency (EPA) is responsible for establishing national emission standards for hazardous air pollutants. According to Section 118, Federal agencies that have jurisdiction over facilities that emit such pollutants shall comply with these standards. The Administrator of EPA reviewed the information concerning radioactive pollutants in response to Section 122 of the Act as amended in 1977 (Public Law 95-95) and determined that radionuclides are hazardous air pollutants (Federal Register 44, 76738-76746, 1979). In Section 103, the Administrator is directed to conduct research and investigations concerning, among other things, the causes and extent of air pollution.

The Office of Radiation Programs (ORP) of the EPA is currently developing standards for radionuclides emitted to air by several source categories (Federal Register 46, 15076-15091, 1983). For most categories, proposed standards are in terms of dose equivalents committed to the most exposed persons in the population. These doses are calculated by ORP on the basis of annual radionuclide emission values reported by the facility and calculational models -- notably, AIRDOS-EPA -- for the transfer of radionuclides from source to humans. The Office of Radiation Programs also performs field studies at selected facilities that emit radionuclides to confirm source-term measurements and pathway calculations for radiation exposures to humans offsite. Described here is the field study at the Savannah River Plant (SRP).

The purpose of the study at SRP was to verify, where possible, reported airborne releases and resulting radiation doses from the facility. Because of the short time available, measurements performed at selected locations during a single field trip were combined with comparisons of predictions from meteorological data, inquiries concerning release points, release rates, and monitoring at SRP. The measurements of

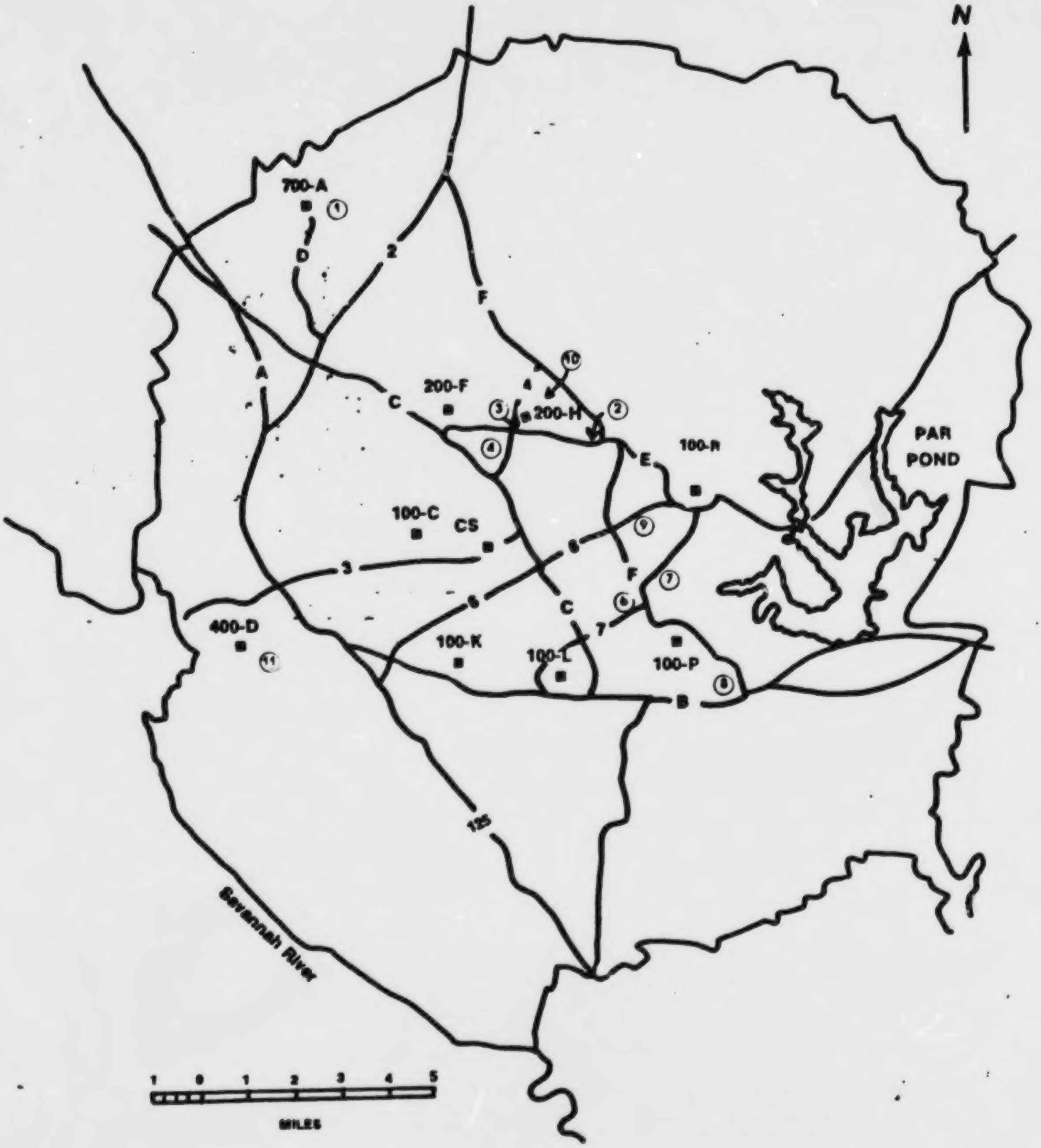
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Fig. 1.1. The Savannah River Plant site

radionuclide releases for brief periods were compared with measurements performed by SRP staff on split samples and with annual average releases reported by SRP for the same facilities. The dispersion model used by SRP staff to calculate radiation doses offsite was tested by brief environmental radioactivity measurements performed simultaneously with the release measurements, and by examining radioactivity levels in environmental samples collected either as part of this study or as part of the SRP monitoring program.

1.2 Plant Description and Effluent Sources

The SRP is operated by E.I. du Pont de Nemours and Company for the U.S. Department of Energy. The plant is located on the Savannah River in South Carolina, approximately 22 km southeast of Augusta, Georgia. It is roughly circular in area with an approximate radius of 15 km as shown in Figure 1.1. Near the center of this area are a number of facilities that release radionuclides to air and water as a result of normal operations. Access to these facilities is controlled, and the entire area is fenced and patrolled, but State Highway 125 passes through the area within 2.5 km of the nearest facility. However, the highway can be quickly closed at the site boundaries if warranted by an unplanned release.

The main function of SRP since it began operating in 1953 is producing tritium and plutonium for the Defense Department. Three heavy-water-moderated reactors in the 100 Area (see Fig. 1.1), designated C, P, and K, produce H-3 and Pu-239 by neutron activation of Li-6 and U-238, respectively. Two additional reactors had been operated, and one of them is scheduled for further use. A heavy-water (H-2) enrichment plant (currently not operating) and a plant to purify and recover contaminated heavy water from the reactors are in the 400 Area.
Three facilities in the 300 Area fabricate fuel and targets for the reactors. Two chemical separation facilities in the 200 Area, designated F and H, dissolve irradiated fuel to recover uranium, neptunium, and

Table 1.1 Atmospheric Radionuclide Releases from the SRP in 1981 (Du82)

Radionuclide Gases and Vapors	Annual Release, Ci	Source: Area number (Ci)
H-3	4.0E+5	100(1.3E5); 200(2.7E5); 400(2.0E3); 700(1.5E1)
C-14	6.9E+1	100(4.1E1); 200(2.8E1)
Ar-41	6.2E+4	100
Kr-85	8.4E+5	200
Kr-85m	1.3E+3	100
Kr-87	8.7E+2	100
Kr-88	1.5E+3	100
Xe-133	3.9E+3	100
Xe-135	2.5E+3	100
I-129	1.6E-1	200
I-131	4.7E-2	100(7.0E-3); 200(3.7E-2)
Xe-131m	6.4E+0	200
Particulates		
Co-58/60	8.9E-5	700
Sr-89/90	3.0E-3	200
Zr-95	1.7E-2	200
Nb-95	6.4E-2	200
Ru-103	1.3E-2	200
Ru-106	7.8E-2	200
Cs-134	6.4E-4	200
Cs-137	3.1E-3	200
Ce-141	3.2E-4	200
Ce-144	2.7E-2	200
U	6.1E-3	200
Pu-238	4.6E-3	200
Pu-239	2.8E-3	200
Am-241/243	4.9E-4	200
Cm-242/244	1.6E-4	200

Notes:
1) Exponential notation; e.g., 4.0E+5 reads 4.0×10^5.
2) Amounts of C-14, Kr-85, and I-129 are inferred from fuel irradiation.
3) H-3 releases of 1.0E+4 from the 100 Area and 4.0E+4 from the 200 Area are estimated to be due to evaporation of water from seepage basins.

plutonium. A major facility for separating, purifying, and packaging H-3 is in the same Area. Research and development are performed in the 700 Area. Radioactive waste is handled and stored at several locations. Low-level radioactive liquid waste is released to open seepage basins and eventually outcrops into small creeks and then into the Savannah River. Gaseous and airborne particulate radionuclides are subjected to various treatments and then released through stacks (see subsequent sections for details) at all of the facilities.

The major radioactive emissions in terms of curie (Ci) amounts ARE Kr-85, H-3, Ar-41, and short-lived fission-produced krypton and xenon radioisotopes (Table 1.1). In general, the shorter-lived radionuclides are discharged from reactor stacks in the 100 Area and the longer-lived radionuclides, from chemical separation plant stacks in the 200 Area. Tritium and C-14 are released at both locations. Of the H-3 releases indicated annually for the 100 and 200 Areas, 1.0 x 10^4 Ci from the former and 4.0 x 10^4 Ci from the latter were estimated to be due to evaporation of water at seepage basins.

According to a recently prepared data compilation from 1954 to 1980 (As82), annual radionuclide releases from SRP have been reasonably constant during the past five years. However, instances of elevated releases indicate the potential for occasionally higher annual values and for residual environmental contamination by the longer-lived radionuclides. Some earlier radioactivity release values have been reduced over the years by improvements in operations and effluent treatment. Occasionally, elevated values are due to unplanned events such as a Pu-238 release in 1969 (See Table 1.2)(Pe79). In 1981, 3.3 x 10^4 Ci of H-3 in the form of water vapor were released from the tritium facility in a 2-hour period on March 27 (HP82).

The release values in Table 1.1 and 1.2 are obtained by stack monitoring that combines continuously recording in-line monitors, collecting and analyzing gas samples, and continuous collection of airborne particulate radioactivity on filters with periodic analysis.

Table 1.2 Highest Radionuclide Releases to the Atmosphere at the SRP in 1954-1980*

Radionuclide	Year	Release, Ci
H-3	1964	1.6E+6
	1974	9.0E+5
Ar-41	1973	1.8E+5
Sr-89/90	1955	4.3E-1
	1972	1.3E-1
Nb-95	1971	2.3E-1
Ru-103/106	1968	2.0E+1
I-129	1955-73	2.1E-1
I-131	1971	2.7E+1
Xe-133	1972	3.9E+4
Cs-137	1955	1.4E+0
Ce-144	1972	3.3E-1
Pm-147	1954	1.2E-1
U	1955	1.9E-1
Pu-238	1969	5.6E-1
Pu-239	1955	2.7E+0

* Highest annual releases among values exceeding 0.1 Ci, from As82.

Table 1.3 Calculated Radiation Dose Equivalent Commitments Due to Atmospheric Radionuclide Releases from the SRP in 1981

Radionuclide	Dose equivalent commitment to the total body		
	MREM (HP82)	GASPAR (Ma82)	AIRDOS-EPA (EPA79)
Maximum exposed individual at plant boundary, mrem/yr			
H-3	0.88	0.74	1.69
C-14	0.066	0.024	0.02
Ar-41	0.18	0.084	0.33
all others*	0.022	0.015	0.23
Total	1.15	0.86	2.27
Population within 80 km, person-rem/yr			
H-3	100.3	57.1	84.6
C-14	7.5	0.91	1.6
Ar-41	8.2	2.8	6.6
all others*	1.6	1.5	6.9
Total	117.6	62.3	99.7

* See Table 1.1 for list of radionuclides; contribution by any single radionuclide to the total is small except, according to AIRDOS-EPA, I-129 is responsible for about 5 percent of the total dose equivalent to the maximum individual and over 1 percent of the total collective dose equivalent.

Releases of C-14 and Kr-85 are computed by SRP staff on the basis of fuel irradiation history and assumption of total discharge. The same procedure was used for I-129 until a monitor was installed during 1981. Release data for some radionuclides are not available for the early years of operation and some values for early years are calculated from operating information and later measurements.

1.3 Off-Site Radiation Exposure and Environmental Monitoring

The radiation dose equivalent commitments from airborne radionuclides discharged at SRP during 1981 were 1 to 2 mrem/yr to the total body of a most exposed person at the plant boundary and 100 person-rem/yr to all persons within 80 km of the plant, according to the three calculational models cited in Table 1.3. The doses are almost entirely due to external radiation from 1.83-hr Ar-41 in the plume from reactor stacks, and from H-3 plus C-14 intake by inhalation and by ingestion of vegetables, milk, and meat. Highest organ doses were to thyroid and skin; they were 1.53 and 1.65 mrem/yr, respectively, and 209 and 134 person-rem/yr, according to the GASPAR code. The elevation of the thyroid dose above the total body dose is predominantly due to ingesting I-129, and the higher skin dose is due to external beta-particle radiation from Ar-41. The calculation for the most exposed person considers food intake and inhalation by a child, the most radiosensitive age group.

The dispersion calculations used to compute doses by the MREM program suggest that H-3 and Kr-85 concentrations in air are detectable at the plant perimeter, and that all other radionuclides are at very low levels (HP82). The average values for 1981 are as follows:

H-3	110 pCi/m^3
Ar-41	8.1
Kr-85	230
Xe-133	1.1

Average concentrations for all other radionuclides were below 1 pCi/m^3; those for radioiodine and particles were in the extremely low range of 10^{-5} to 10^{-8} pCi/m^3. Concentrations at the perimeter could be higher by one to two orders of magnitude for downwind periods or occasions of higher than average releases.

In utilizing these computer codes, SRP staff (for the MREM and GASPAR codes) and EPA staff (for the AIRDOS-EPA code) made various simplifications that they consider will not affect the results significantly. Among the major assumptions were that all airborne radionuclides are released at a single stack near the center of the plant area; that radionuclide release is uniform throughout the year; that dispersion is on the basis of a joint frequency tabulation for meteorological factors derived for earlier years; that maximum exposure occurs at the point of highest airborne concentrations at the plant boundary and that locations of farms that grow the contaminated foods are uniformly distributed; that persons were exposed throughout the whole year without shielding and for specified fractions of local food consumption; and that H-3 and C-14 were in the forms of water and carbon dioxide, respectively, that entered the exposure pathways as isotopic tracers.

The main evidence of airborne radioactive discharges from SRP found by the environmental monitoring program routinely performed by its staff is H-3 in air moisture, rainwater, vegetation, and milk and food, AS SHOWN IN TABLE 1.4. Even at distances of 25 to 100 km, H-3 levels are still above the analytical instrument's lower limit of detection of 0.3 pCi/ml. It is possible that some Pu-238 and Pu-239 concentrations in soil collected at the perimeter are slightly elevated in comparison to background concentrations. All other radionuclide concentrations in samples from the plant perimeter are similar to those taken at greater distances from the plant and to those found in sampling networks at other sites.

Radiological environmental monitoring samples collected routinely by the Georgia Environmental Protection Division near SRP in Georgia show the same pattern of radionuclide levels as the SRP monitoring programs.

Table 1.4 Summary of Environmental Radiological Monitoring Results at the SRP in 1981 (HP82)

Sample	Radionuclide	Units	Radionuclide ranges: Plant perimeter	Radionuclide ranges: Distant (25-100 km)
Air moisture	H-3	pCi/ml	29 - < 0.3	8.5 - < 0.3
Airborne particles	Sr-89/90	fCi/m^3	3 - < 1	3 - < 1
	Pu-238	aCi/m^3	9.6 - < 0.4	4.7 - < 0.4
	Pu-239	aCi/m^3	31 - < 0.9	44 - 0.9
	gamma(Cs-137)	fCi/m^3	9.7 - 0	11 - 0
rainwater	H-3	pCi/ml	36 - < 0.3	5.7 - < 0.3
	gamma(Cs-137)	nCi/m^2	0.32 - < 0.08	0.33 - < 0.08
	Sr-90	nCi/m^2	0.85 - 0.02	0.94 - 0.10
	Pu-238	pCi/m^2	1	8 - 0.1
	Pu-239	pCi/m^2	8	6 - 0.8
vegetation	H-3	pCi/ml	22 - < 1	8 - < 1
	gamma(Cs-134/137)	pCi/g	0.7 - 0	7.4 - 0
milk	H-3	pCi/ml	4.2 - < 0.3	1.2 - < 0.3
	I-131	pCi/l	9 - < 1	10 - < 1
	Cs-137	pCi/l	13 - < 3	10 - < 3
food (vegetable, fruit, grain, meat)	H-3	pCi/ml	9 - < 1	---
	gamma(Cs-137)	pCi/g	0.10 - 0.02	---
	Sr-90	pCi/g	1.1 - 0.1	---
soil	Cs-137	pCi/g	0.71 - 0.02	0.58 - 0.54
	Pu-238	fCi/g	2 - 1	1
	Pu-239	fCi/g	16 - 10	10 - 9
external radiation	gamma	mR/yr	91 - 55	124 - 55

Elevated H-3 concentrations, of the order of 1 pCi/ml, were found in air moisture, rainwater, and milk. Levels of the photon-emitting radionuclides in these media and in vegetation and soil were similar to values elsewhere, and were attributed to fallout from nuclear weapon tests and to naturally occurring radioactivity (EP82).

Special studies are in progress concerning the transport of Kr-85, I-129, and Pu-238/239 through the environment at SRP. Although Kr-85 and I-129 are not measured in the routine environmental monitoring program, these special studies provide information on the migration of specific radionuclides in the environment. A network of Kr-85 sampling stations was operated in 1975-6 at distances as great as 140 km from the SRP to test air dispersion models. Off-site concentrations of Kr-85 as high as 420 pCi/m^3 were observed, and even at the distant stations Kr-85 was detected above the ambient background levels of 14 pCi/m^3 (Pe79). Plutonium studies have shown readily detectable concentrations in 200-Area soil due to accidental releases in earlier years. The concentration of plutonium in soil was found to decrease logarithmically with distance, reaching approximately background values at the plant boundary; in soil cores to a 15-cm depth, Pu-238 and Pu-239 concentrations were 0.2 - 0.8 fCi/g and 1-9 fCi/g, respectively, outside the perimeter (Mc76). A soil and a grass sample collected at Jackson, South Carolina near SRP contained I-129/I-127 atom ratios of 4 x 10^{-6} and 1 x 10^{-5} respectively, compared to background ratios of the order of 1 x 10^{-7} (Ba74). The corresponding I-129 concentrations in the two samples were 0.6 and 0.9 fCi/g, while background values were near 0.02 fCi/g. Systematic measurements of I-129 in soil and vegetation indicate average levels of 400 pCi/m^2 near the perimeter, decreasing gradually with distance, but still 6 pCi/m^2 at 150 km. This compares to background levels of 0.2 pCi/m^2. At the highest I-129/I-127 atom ratio of 2 x 10^{-5} near the plant boundary, the annual dose to the adult thyroid could be 1.6 mrem (Ka82).

1.4 The Study

The study was undertaken on December 13-15, 1982. On December 13, SRP staff presented information concerning radionuclide sources, airborne discharges, effluent air treatment and radionuclide measurements, and calculations of radiation doses to persons off-site. The EPA staff presented its study plans. Arrangements were made for collecting samples, undertaking the field study, and obtaining data concerning releases and meteorological conditions. Sampling was performed on December 14 and 15.

The component activities of this type of field study are collection of samples at airborne radioactivity release points, measurement of radionuclide concentrations in surface air nearby, and collection of exposure pathway samples such as food, vegetation and soil. Effluent samples are used to check the magnitude of reported annual releases, to compare with duplicate sample analyses by plant staff, and to provide the source term for samples collected simultaneously in ground-level air. Radionuclide concentrations in surface air are compared with release rates to test the calculational disperson model. Other environmental samples are used as radionuclide collectors (integrators) and to compare with results from the plant environmental monitoring programs.

At the time of the study, the reactors and the tritium facility were in routine operation, but the chemical separation facilities were not. Effluent samples were, therefore, collected from the tritium facility and one of the reactors (P), and surface air samples were collected 1-5 km downwind from these facilities, the former on December 14 and the latter on December 15. The samples of airborne radionuclides included compressed air, particulate filters, and condensed moisture. External radiation from the reactor effluent plume was also measured downwind. The SRP staff provided aliquots of particulate effluent samples collected at one of the chemical separation facilities stacks during this period, and also one from several days earlier, when the facility was processing irradiated fuel. Samples of vegetation and soil from the plant site and of vegetable, beef, and milk off-site were also collected for analysis. The locations of all sampling sites are listed in Table 1.5.

Some radioactivity measurements were performed on site in mobile laboratories. Samples were then taken to the EERF laboratory in Montgomery, AL for radiochemical separations, more sensitive analyses, and observations of radioactive decay. Measured concentrations of radionuclides in surface air were compared with concentrations computed with the AIRDOS-EPA code on the basis of release rates and meteorological data supplied by the SRP meteorology group.

Table 1.5. Locations of sampling sites

Site 1 - Behind building No. 735A in 700 Area.

Site 2 - Intersection of Roads E and F (NW quadrant).

Site 3 - Intersection of Roads 4 and E (NE quadrant).

Site 4 - Intersection of Roads 4 and C (NW quadrant).

Site 5 - Open.

Site 6 - On Road 7, 460 m (1500 ft) west of intersection with Road F.

Site 7 - On Road 7, 400 m (1300 ft) east of intersection with Road F.

Site 8 - At intersection of Roads F and B (NW quadrant).

Site 9 - On Road 6, 610 m (2000 ft) east of intersection with Road F.

Site 10 - "Farming area" on the northeast edge of H Area.

Site 11 - 400 D Area at Monitoring Station (Building 614).

Site 12 - Seven miles north of Aiken.

Site 13 - In Jackson, South Carolina.

Site 14 - In Langley, South Carolina.

Site 15 - Near the intersection of Highways 19 and 302.

Note--The locations of these sites are shown on maps in Figures 3.4 and 4.4.

2. AIRBORNE RADIOACTIVE DISCHARGES*

2.1 The Tritium Production Facility (H-Area)

The tritium facilities are a complex of buildings in which tritium is separated from irradiated targets, further purified, and packaged. Operations are carried out in well-ventilated areas and process cabinets in which air movement sweeps any unavoidable tritium releases out the stacks. A large chemical separations plant is also located in H-Area. This plant processes reactor irradiated enriched uranium to recover uranium isotopes, ^{237}Np and ^{238}Pu. Description of this facility is included in Section 2.3.

2.1.1 Gaseous Effluent System. The tritium facilities are served by three 200-ft. stacks and one 75-ft. stack, which normally exhaust a total of about 279,000 ft^3 of air per minute. Tritium in this exhaust air, at very low concentrations, arises from sources such as exhaust gas streams, leaks, maintenance work, handling the targets, loading and unloading the extraction furnace, and packaging operations.

Releases from the tritium process buildings can be categorized according to the controls that are imposed on the specific streams. Tritium escapes in very low concentrations in the discard of discrete batches of inert gas or air, in disposal of the light hydrogen isotopes as waste from the isotopic separations, and in unavoidable releases into the general ventilation system (from leaks, opening equipment, etc.).

The first category of release is individual batches of inert gas or air. Absorption beds are used where feasible to reduce the amount of tritium that otherwise would be lost this way. One system in use has an oxidizing bed to convert any elemental tritium into water, followed by a zeolite bed to absorb the water; another system requires only the zeolite beds.

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* Much of the descriptive material presented in this section was abstracted from Du82.

A second category of release is from the purification operations in which tritium (^3H) is separated from protium (^1H) and deuterium (^2H). The final fraction is analyzed for tritium before release and is recycled if the tritium is recoverable.

2.1.2 Source Sampling. Stack sampling at the tritium production facility is performed on a continuous basis with Kanne Ionization Chambers and tritium species monitors that measure the tritium concentrations and determine the ratio of elemental to oxide forms. Composite tritium release data for the area were provided by SRP personnel for purposes of comparison with environmental sampling. Total tritium released during the environmental sampling period (9:00 a.m. to 3:00 p.m., December 14, 1982) was 154 Ci at 7,130 μCi/sec, composed of 62 percent tritiated water vapor and 38 percent elemental tritium (Ra82). Extrapolating from this information, an annual estimate of approximately 2.25 X 10^5 Ci/yr of tritium would be released from this area, which would include approximately 1.40 X 10^5 Ci/yr of tritiated water and 0.85 X 10^5 Ci/yr of elemental tritium. This total compares closely with reported releases of 2.7 X 10^5 Ci for these facilities during 1981 (Du82).

2.2 The Reactor Facility

At the time of this study, there were three operating reactors at the Savannah River Plant. These were the P, K, and C reactors. The P reactor was selected for measurements during this study because of its remote location from other sources. The P reactor is one of five original reactors at SRP that is uranium fueled with heavy water (D_2O) used as a moderator and coolant. Secondary cooling is provided by once-through water from the Savannah River. These reactors are production reactors that are designed specifically to create excess neutrons that can be used to make specific isotopes. They do not produce steam or electricity. Power levels for these reactors are variable; however, they typically operate at around 2,000 megawatts-thermal.

Airborne releases from the reactor facilities are responsible for nearly one-half the off-site airborne radiation dose. The major radionuclides contributing to the off-site dose are tritium, carbon-14, argon-41, and krypton-xenon. Reported releases for 1981 for the three operating reactors are shown in Table 2.1 (Du82).

Table 2.1 Airborne releases in curies from reactor areas in 1981

Nuclide	P Area	K Area	C Area	Total
Tritium	2.5E+4	5.7E+4	3.3E+4	1.15E+5
Carbon-14	1.4E+1	1.3E+1	1.4E+1	4.1E +1
Argon-41	2.0E+4	2.0E+4	2.3E+4	6.3E +4
Krypton-85m	7.0E+2	3.3E+2	2.7E+2	1.3E +3
Krypton-87	2.6E+2	4.3E+2	1.9E+2	8.8E +2
Krypton-88	4.6E+2	6.1E+2	4.1E+2	1.5E +3
Xenon-133	2.4E+3	1.1E+3	3.9E+2	3.9E +3
Xenon-135	1.3E+3	9.1E+2	3.7E+2	2.6E +3
Iodine-131	3.4E-3	1.5E-3	2.1E-3	7.0E -3
Total Alpha	1.1E-6	3.6E-6	4.0E-6	8.7E -6
Other Beta-Gamma	1.5E-4	4.2E-4	3.3E-4	9.0E -4

2.2.1 Gaseous Effluent System. Radionuclides are released to the atmosphere as a result of routine operation of P, K, and C Reactors from three atmospheric release points--

- at the 200-foot-high stack,
- at ground level from evaporation of disassembly basin water,
- and at ground level from evaporation of water purged from the disassembly basin to a seepage basin.

Tritium Stack Releases

Tritium, in the form of DTO, is released to the ventilation system and, therefore, to the stack by evaporation of process water exposed to air flowing through the process area. During reactor operation, small amounts of D_2O containing DTO are evaporated from slow leaks in pipe flanges, valves, and from exposed D_2O process water. During reactor shutdown, DTO is evaporated when pipes or valves are opened for inspection and maintenance work, and when wet fuel, targets, and control rods are removed from the reactor. Releases of tritium from the stack are continuously monitored by on-line Kanne Chambers and by collecting dehumidifier samples daily and analyzing the condensate for tritium.

Tritium Releases from the Disassembly Basin

Although the discharged fuel and target assemblies are rinsed with water before being placed in the disassembly basin, some tritium is transferred to the disassembly basin with process water that adheres to the assemblies. Some water vapor containing DTO evaporates at ground level from the disassembly basin and from the seepage basin to which the disassembly basin water is occasionally purged.

Tritium Releases from the Seepage Basin

Disassembly basin water is normally recirculated through filters and deionizers to clarify the water and to remove radionuclides. Tritium is not removed in the process. When the tritium content of the disassembly basin water has built up through several reactor discharges to a procedural control range of 0.2 to 0.4 microcuries/ml, water is purged to a seepage basin through filters and deionizers. This controls the airborne tritium levels in the plant and the consequent exposure to plant workers. Based on average atmospheric conditions, 30 percent of the tritium thus purged evaporates from the basin each year.

Releases of Other Radionuclides

Fission product noble gases (isotopes of xenon and krypton) are released to the reactor coolant from small defects in fuel and target assemblies and occasionally, but rarely, from failures in the depleted uranium target assemblies. The gases diffuse to the helium blanket gas system and, because of leaks in the pressurized gas system, can enter the process ventilation system, where they are released from the 200-foot stack. Noble gas releases are continuously monitored using a Ge-Li detector system and reported hourly by remote readout (Du82).

Argon-41 is produced by neutron irradiation of natural argon in the air space that exists between the reactor tank wall and the thermal sideshield. The radioactive argon (1.83-hour half-life) diffuses to the process area ventilation system and is released from the 200-foot stack. The confinement system filters, consisting of moisture separators, particulate filters, and carbon beds do not prevent the release of tritium and noble gases to the atmosphere.

Carbon-14 is produced in the moderator in three ways: from (n, α) reactions with naturally occurring ^{17}O in the D_2O process water, from (n, p) reactions with ^{14}N present as dissolved gas in the moderator or as nitric acid used to control the moderator pH, and from irradiation of ^{17}O present in the air around the reactor tank wall. Most of the carbon in the moderator is removed as carbonates by the moderator ion-exchange purification system. Some of it, as CO_2, enters the pressurized blanket gas system and is exhausted through the stack. The calculated total annual releases of ^{14}C from the three reactors operating at SRP for the three periods, 1978, 1979 and 1980, were 34, 33, and 41 curies, respectively.

Iodine-131, a fission product, is released to the process room air by the same pathways as xenon and krypton. The fraction of iodine released through the carbon filters is $5X10^{-5}$ (Du82). Releases of particulate radionuclides and I-131 are continuously monitored using Gelman (type A-E) filter paper and charcoal filters, respectively.

2.2.2 Source Sampling. Samples of air being released from the stack at the P-reactor were obtained through the facility's sampling system. This system included a 1.0 inch line running from the 148 foot level on the stack to a sampling room where particulate and charcoal filters could be accessed. Flow through the line was maintained at 1 cfm. Filters are routinely changed once each week, however, both the particulate and charcoal filters were obtained on the morning following environmental sampling (December 16, 1982). The total sampling time for these filters was 3 days and included a volume of 122 m^3. Stack flow during the study was 46 m^3/s.

Gaseous samples were collected by EPA personnel from the sampling system on December 15, during the time environmental samples were being collected. The gaseous samples included two sealed Marinelli beakers, each having a volume of 1.16 liters. The two beakers were simultaneously filled by flowing air from the sampling system through the two beakers in series. Air was allowed to flow through the beakers at a rate of about 1 cfm for five minutes (approximately 120 volumes). The port in the sample supply system used in collecting these samples was downstream from the particulate and charcoal filters.

In addition to the Marinelli beakers, two small gas cylinders were used to contain approximately 20 liters of air from the sample port. A small compressor was used to collect the samples at a pressure of approximately 400 psi. A sample of water from the reactor dehumidifier condenser was also obtained for tritium measurements.

Filter samples including both particulate and charcoal samples from the exhausts of each of the three operating reactors for the week of December 6 through 13, 1982, were also obtained. These samples were split with the SRP Laboratory for comparison of analytical methods and measurements. Results of the analysis of these samples appear in Appendix A.

2.2.3 Analyses. The 72-mm fiberglass filters and the charcoal were analysed for gamma emitting isotopes with a high purity germanium detector and spectroscopy system located in the EPA mobile laboratory at

SRP. The initial analysis was started approximately 1 hour after the filters were removed from the reactor. Gaseous samples in the 1.16 liter Marinelli beakers were also analysed for gamma emitting radionuclides on site 55 minutes after collection. After the initial analysis, all filter samples were returned to SRP Laboratory personnel to split the samples for comparison analysis. Fiberglass particulate filters were cut in half and charcoal sample portions were weighed to provide both EPA and SRP with samples. The EPA portions of these filters and the small gas cylinders were returned to the EPA-EERF laboratory for additional analyses.

Analyses at EERF included gamma spectroscopy on filter and charcoal samples. The fiberglass filters were then chemically treated to perform individual analyses for isotopes of uranium, plutonium, americium, and strontium (Li83). Gaseous samples were tested for Kr-85, using a cryogenic separation system (St71), and for tritium and C-14 (Go75).

2.2.4 Results and Discussion. Concentrations and release rates for the radionuclides found in these samples are listed in Table 2.2. Analysis of the particulate filters resulted in activities below detectable limits for all radionuclides except uranium-238. Charcoal samples were analyzed specifically for iodine-131 and also were below detectable limits.

Water obtained from the stack dehumidifier system was measured for tritium content and a concentration of 1.97 ± 0.07 μCi/ml was measured. Based on a moisture content of 23 grains per pound (4.25 g/m^3) for the stack effluent and a flow rate of 46 m^3/s a release rate of 385 ± 14 μCi/s was calculated. This compares closely with activities of 1.93 μCi/ml (377 μCi/s) measured by SRP or 30 Ci/day (347 μCi/s) based on Kanne chamber measurements at the reactor (Ra83). Results of measurements by EPA and SRP for tritium and noble gases are compared in Table 2.3.

Gaseous stack samples from the P-reactor were analyzed for noble gases and carbon-14. The results of the measurements (Table 2.2) indicate that the noble gases make up the majority of the radioactive materials released from the reactor facilities during normal operations. The failure to detect Xe-133 was probably due to an unusually high analyzer discriminator setting (> 80 KeV) that was necessary to eliminate excessive low-energy pulses due to noise in the power source that was later corrected. Also, the value listed for Kr-88 is based on the counts in the 196 KeV peak. However, the other peak at 835 KeV was much smaller than anticipated, indicating that the count rate at 196 KeV was only partially due to the presence of Kr-88. Thus, it is most likely that the Kr-88 release rate is something less than the 25 μCi/s estimated using the count rate at 196 KeV.

Comparison of the estimated release rates based on these measurements and the release rates measured with the SRP noble gas monitoring system are shown in Table 2.3. Although good agreement is noted for the major radionuclides, there are some significant differences. Some of these differences may result from comparison of single grab samples of stack effluent obtained by EPA with average measurements made by the SRP monitoring system. Also, as indicated above, it is most likely that the EERF may have estimated a high value for Kr-88.

Table 2.2 Stack Effluent Samples from P-Reactor

Type Sample	Radionuclide	Measured Concentration µCi/m^3	Estimated Release Rate µCi/s
Particulates	Gamma emitting	< 8E-8	< 4E-6
Particulates	Sr-89	< 4E-8	< 2E-6
Particulates	Sr-90	< 8E-9	< 4E-7
Particulates	U-234	< 3E-9	< 2E-7
Particulates	U-235	< 3E-9	< 2E-7
Particulates	U-238	(1.1 ± 0.3)E-8	(5 ± 2)E-7
Particulates	Pu-238	< 1E-9	< 6E-8
Particulates	Pu-239	< 1E-9	< 6E-8
Particulates	Am-241	< 1E-9	< 6E-8
Charcoal	I-131	< 3E-7	< 1.3E-5
Water	H-3	(8.4 ± 0.3)E+0	(3.9 ± 0.1)E+2
Stack gas	C-14	(7 ± 2)E-3	(3.4 ± 0.8)E-1
Stack gas	Ar-41	(2.8 ± 0.2)E+1	(1.31 ± 0.09)E+3
Stack gas	Kr-85	(1.2 ± 0.2)E-5	(5 ± 1)E-4
Stack gas	Kr-85m	(2 ± 1)E-1	(9 ± 6)E+0
Stack gas	Kr-87	(1.4 ± 0.9)E-1	(6.4 ± 0.4)E+0
Stack gas	Kr-88	(5 ± 2)E-1	(2.5 ± 1.1)E+1
Stack gas	Xe-133	Not Measured	
Stack gas	Xe-135	(8 ± 1)E-1	(3.9 ± 0.6)E+1

Notes: 1) Samples were collected during the following periods; particulates from 0830 on 12/13 to 0830 on 12/16, water from 0830 on 12/15 to 0830 on 12/16, and stack gas at 1400 on 12/15.

2) Particulate filter samples were split between SRP and EPA, and results shown are estimates based on assumption of equal portions.

Table 2.3 Source Term Comparison - P-Reactor

Radionuclide	μCi/s	
	SRP (Ra83)	EERF
H-3 (12.28 y)	377	385 ± 14
Ar-41 (1.827 h)	1053	1308 ± 88
Kr-85m (4.48 h)	17.4	8.9 ± 5.9
Kr-87 (1.272 hr)	6.1	8.6 ± 0.4
Kr-88 (2.84 h)	9.0	25 ± 11
Xe-133 (5.24 d)	14.4	Not detected
Xe-135 (9.11 h)	29	38.7 ± 5.8

2.3 The Chemical Separation Facilities

The chemical separation facilities consist of two separate facilities (F and H) that process irradiated fuel and uranium target materials. Each separation plant is in a large shielded building called a "Canyon" for processing the highly radioactive materials. In F Area, ^{239}Pu, ^{237}Np, and ^{238}U are recovered using the Purex solvent extraction process. This area also contains the main analytical laboratory, the plutonium metallurgical laboratory, and the plutonium fuel fabrication facility.

The H Area is used to extract special radionuclides, including ^{237}Np and ^{238}Pu, as well as ^{235}U, from irradiated uranium enriched in its 235 content. H-Area also contains the Tritium Production Facilities described in Section 2.1, the Receiving Basin for Offsite Fuels, and the Resin Regeneration Facility.

Releases from these separation areas result in somewhat over half the estimated total SRP off-site radiation dose from radioactive airborne emissions. The primary radionuclides contributing to the off-site doses from these facilities are tritium, carbon-14, and the isotopes of Kr and Xe (Du82). Emissions from the combined separation areas during 1981 are shown in Table 2.4.

Table 2.4 Airborne Releases in Curies from Separation Areas in 1981

Nuclide	Total
Tritium	2.7E+5
Carbon-14	2.8E+1
Krypton-Xenon	8.4E+3
Iodine-129	1.6E-1
Iodine-131	3.7E-2

2.3.1 Gaseous Effluent System

In the chemical separation process, reactor irradiated materials are dissolved, then chemically treated to separate the various products. Major products and byproducts include isotopes of plutonium, uranium, and neptunium. Airborne effluents from each separation process passes through individual filtration systems prior to flowing into a common sand filter and release from a 200 foot stack. The stacks are continuously monitored for particulates, radioiodine, and krypton-85.

Off gases and particulate radioactivity from most other operations conducted at these facilities pass through HEPA filters, sand filters, or both before being discharged through facility stacks. Particulate, radioiodine, noble gases, and tritium releases are monitored at the major stacks.

2.3.2 Source Sampling. Particulate filters (72-mm fiberglass) and charcoal filters for the period of December 5 through 12 and for December 14 through 15 were provided by the SRP sampling system. These samples were intended to be for comparative purposes. Samples of the earlier period represented conditions of normal operation, while samples of the latter period were collected during reduced operations. In addition, samples of air being released by one of the plants during operation were collected on a later date by SRP personnel and sent to EERF. Results of the samples obtained for comparison purposes are shown in Appendix A.

Table 2.5 Chemical Separations H-Area Stack Effluent Samples

Radionuclide	Measured Concentration (pCi/m^3)	Estimated Release Rate (pCi/s)
Zr-95	1.6 ± 0.2	220 ± 20
Nb-95	0.98 ± 0.09	140 ± 10
Ru-103	2.9 ± 0.2	410 ± 20
Ru-106	31 ± 1	4400 ± 180
Cs-134	0.082 ± 0.005	11 ± 7
Cs-137	0.23 ± 0.05	32 ± 7
Ce-144	2.3 ± 0.7	330 ± 100
Sr-89	< 8.0	< 1100
Sr-90	< 1.6	< 220
U-234	0.04 ± 0.01	6 ± 2
U-235	< 0.0065	< 0.91
U-238	0.017 ± 0.006	2.4 ± 0.8
Pu-238	0.22 ± 0.03	31 ± 4
Pu-239	0.003 ± 0.002	0.4 ± 0.3
Am-241	< 0.0025	< 0.34
I-131*	< 0.15	< 21

Notes: 1) Particulates were collected during the period 0900 on 12/14 to 0900 on 12/15 and iodine was collected during the period 0900 on 12/7 to 0900 on 12/14.

2) Particulate filter samples were split between SRP and EPA, and results shown are estimates based on assumption of equal portions.

* Charcoal filter sample. All other samples are particulate filters.

Environmental samples were not collected around these facilities during the study because the facilities were not processing irradiated fuel at that time.

2.3.3 Analyses. Particulate and charcoal filters were split by SRP laboratory personnel and a portion of each provided for comparative measurements. These samples were analysed for gamma emitting radionuclides with a high purity germanium detector and spectroscopy system at the EERF. Fiberglass particulate filters were chemically prepared and analyzed for the actinides and strontium (Li83). Gaseous samples were analyzed for krypton-85 with a cryogenic separation process (St71).

2.3.4 Results and Discussion. Lists of the radionuclides found in the samples from the H and F chemical separation plants are shown in Tables 2.5 and 2.6, respectively. The radionuclides found include several fission products in addition to isotopes of plutonium and uranium. Although no Np-237 was detected in these samples, any present would have followed the plutonium separation and been partially obscured in the spectral analyses by the Pu-242 tracer peak. No specific analyses for Np-237 were attempted.

Neither plant was operating at normal capacity during the time these samples were collected so these concentrations and release rates are not indicative of either normal or maximum values. The sample volume for the H-facility was 61.2 m^3 and 122.3 m^3 for the F-facility. The stack flow rate at both facilities was assumed to be 140 m^3/s.

The gaseous samples collected by SRP personnel and sent to EPA for Kr-85 analysis were found to contain an average concentration of 85.8 $\mu Ci/m^3$, which would correspond to a release rate of 12.0 mCi/s from either plant. If this rate were maintained continuously, an estimated total of approximately 7.6 x 10^5 curies of krypton-85 would be released per year from the two chemical separation facilities.

Table 2.6 Chemical Separations F-Area Stack Effluent Samples

Radionuclide	Measured Concentration (pCi/m^3)	Estimated Release Rate (pCi/s)
Zr-95	1.04 ± 0.06	144 ± 9
Nb-95	1.24 ± 0.04	174 ± 5
Ru-106	1.5 ± 0.2	204 ± 28
I-131	0.02 ± 0.01	3 ± 2
Cs-137	0.06 ± 0.02	9 ± 3
Ru-103	0.52 ± 0.04	74 ± 4
Ce-141	0.03 ± 0.02	4 ± 3
Ce-144	0.58 ± 0.08	80 ± 10
Sr-89	< 2.0	< 280
Sr-90	< 0.4	< 56
U-234	0.11 ± 0.03	15 ± 4
U-235	< 0.033	< 4.6
U-238	1.2 ± 0.2	170 ± 20
Pu-238	0.010 ± 0.009	1.4 ± 1.3
Pu-239	0.02 ± 0.01	2 ± 1
Am-241	< 0.001	< 0.017
I-131*	0.07 ± 0.01	10 ± 2

Notes: 1) Particulate samples were split between SRP and EPA, and results shown are estimates based on assumption of equal portions.

2) Particulates were collected during the period 0900 on 12/14 to 0900 on 12/15 and iodine was collected during the period 0900 on 12/7 to 0900 on 12/14.

* Charcoal filter sample. All other samples are particulate filters.

3. RADIOACTIVITY IN THE PLUME

3.1 The Tritium Production and Special Radionuclide Facility (Area H)

3.1.1 Meteorology and Sampling Sites. The plume from the stacks of the tritium facility was sampled at near ground level from 0945 to 1439 on December 14, 1982. During this period, the wind dispersion data were continuously recorded by the meteorological station located at H-Area as well as at six other points on the Savannah River Plant (SRP). Ventilation wind profile data were also available at seven heights from a television station antenna to the northwest of the SRP. All dispersion estimates made for releases from H-Area were based on a compilation of 15 minute averages of wind characteristics as obtained from the local H-Area station. These summaries included data on average wind azimuth, vector-averaged wind speed (and speed of maximum wind gust), standard deviation of wind direction measured in the horizontal plane (σ_θ) and standard deviation of wind direction measured in the vertical plane (σ_ϕ). An example plot of plume trajectory for the 15 minute interval ending at 1400 is given as Figure 3.1 with the corresponding table of all simultaneously recorded meteorological data shown as Figure 3.2. Wind stability class was assigned for each 15 minute measurement interval using the method developed by Markee (Ma63), which is based on a correlation between σ_θ and the atmospheric stability. Standard deviations in crosswind plume concentrations σ_y and vertical plume ~~correlations~~ CONCENTRATIONS σ_z were then obtained for each measurement interval using the stability class obtained above and tables of σ_y and σ_z given by Turner (Tu70). Using these data, estimates of ground level plume concentrations were made for each 15 minute interval during each period of sampling.

Two sampling sites for tritium, Nos. 3 and 4, were picked downwind of the 200-foot stacks in H-Area where ground-level concentrations would be near maximum values (see Fig. 3.3). Sampling site 3 was located at a bearing of 220° and less than a kilometer from the tritium stacks (0.93 km).

DATE: 12/14/82 TIME: 1:59:59 PM EST
15 MINUTE-AVERAGED WIND FROM 31.DEG AT 5.1MPH

H AREA

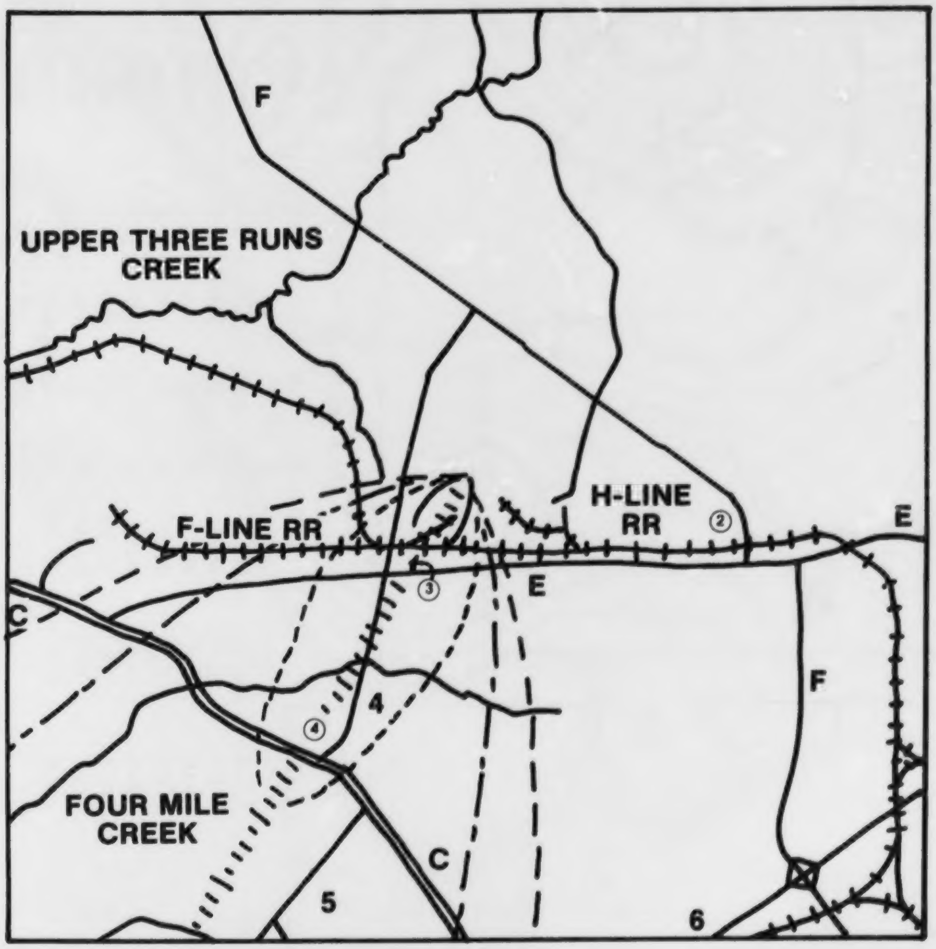
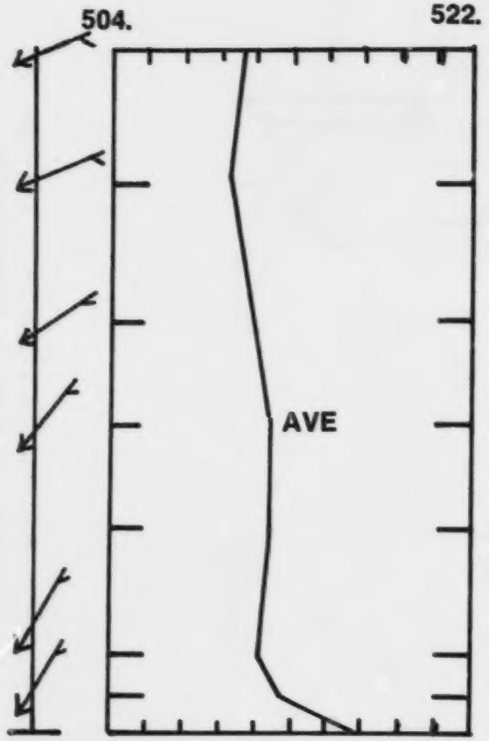
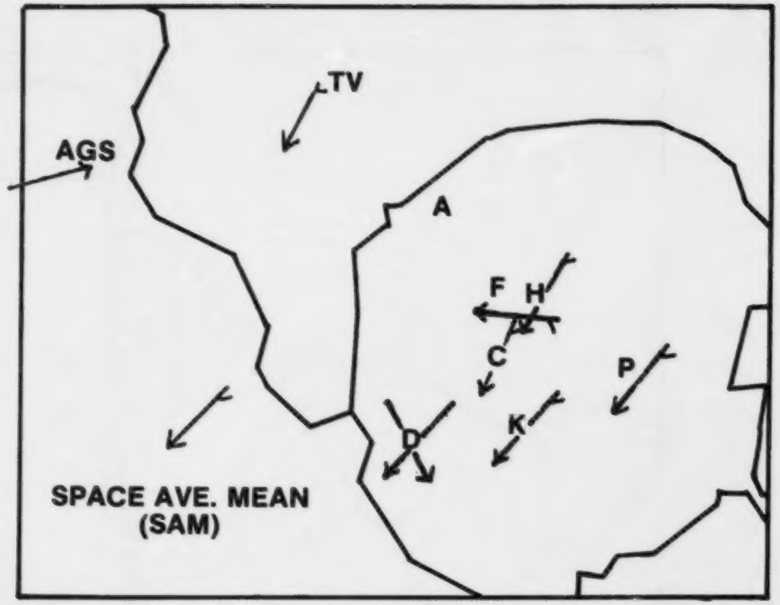

F
UPPER THREE RUNS
CREEK
H-LINE
RR
②
E
F-LINE RR
③
E
C
F
4
④
FOUR MILE
CREEK
C
5
6

Fig. 3.1. An example plot of a 15-minute averaged plume profile in H-Area. Sample site numbers are circled. Large letters and numbers designate roads.

14.9 MIN ENDING: 18:59:59 Z 12/14/82 1:59:59 PM EST 12/14/82





HT	AZM	SPD/GST(MPH)		SIGA	SIGE	TEMP F
999F	68.	5.2	9.3	14.1	14.4	45.53
800F	66.	4.1	7.7	16.6	16.9	45.78
600F	56.	4.1	8.3	31.6	21.3	47.97
450F	46.	4.8	8.5	16.4	19.5	32.00?
300F	0.	0.0?	0.0?	25.8	4.0	50.54
120F	24.	2.9	7.0	30.3	0.0?	50.94
59F	26.	3.4	7.2	34.9	22.3	52.43
7F						56.51

AREA	AZM	SPD/GST(MPH)		SIGA	SIGE
A	0.	? 0.0	0.8	0.0?	0.0
C	22.	4.5	9.4	21.4	11.4
D1	336.	2.2	8.5	50.8	14.3
D2	43.	2.5	7.2	72.9	20.6
F	97.	4.5	9.1	18.6	11.6
H	31.	5.1	11.6	30.5	23.2
K	41.	3.5	10.1	39.6	14.6
P	40.	4.8	9.4	17.7	17.1
TV	24.	2.9	9.3	27.6	2.4
SAM	42.	4.0	11.6	25.9	14.4
AGS	260.	1.8	(49.0/	30.0	ST:2)

Fig. 3.2. SRP site meteorology for the 15-minute interval ending at 2 PM EST on December 14, 1982

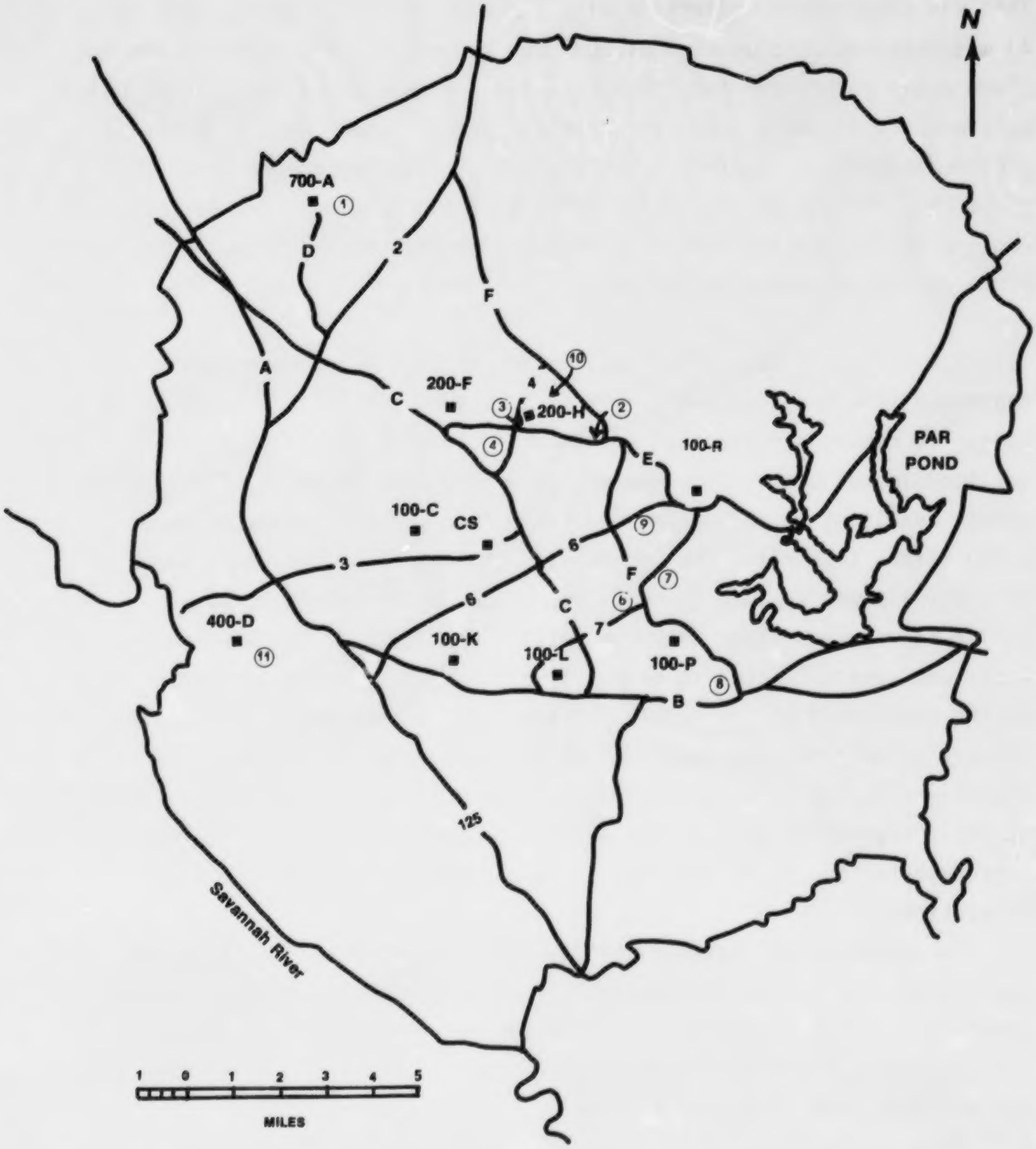

N
700-A
①
D
2
F
A
C
200-F
4
⑩
③
200-H
②
④
E
100-R
PAR
POND
100-C
CS
⑨
6
3
F
⑦
6
C
⑥
7
400-D
⑪
100-K
100-L
100-P
⑧
B
125
Savannah River
1 0 1 2 3 4 5
MILES

Fig. 3.3. The Savannah River Plant Site showing sampling locations. The sampling site numbers are circled with arrows pointing to exact location. Letters and bold type numbers designate roads.

This was the nearest collection site. A more distant sampling site (No. 4) was selected at a bearing of 209° and 2.6 km from the stacks where the plume would be broader and, thus, provide a higher probability of sampling continuously in the plume. In addition, sites 1 and 2 were selected to provide background samples: Site 1 was a distant background site (~ 11 km), while site 2 was at a bearing of 100° and near the facility (only 2.48 km distant), but, due to the wind direction, was never in the plume during the sampling period.

3.1.2 Sample Collections and Measurements. Water vapor was condensed from the atmosphere at each site by pulling air through first a filter to remove particulates and then a cold trap submerged in a dry-ice/alcohol bath. Air flow was generally between 10 to 12 liters per minute resulting in collecting the water from a total volume of about 2,100 liters (2.1 m^3). The removal and collection of the water vapor from the air was assumed quantitative, because the amount of water collected was consistent with the relative humidity of the air and no water was ever collected in backup traps when used during earlier tests. At the conclusion of the sampling period, the frozen vapor in the trap was allowed to melt and the resultant water transferred to a scintillation counting vial for later measurement of the tritium that existed as HTO. During the sampling period, the average temperature and relative humidity were reported by the Meteorology Section to be 11°C and 50 percent, respectively.

To determine the gaseous tritium (HT) concentration of the plume, air samples were collected by opening 1-liter evacuated gas bottles to the atmosphere and then sealing for later laboratory analysis. Samples of this type were collected at 0910 at site 1, at 1200 and 1410 at site 3, and at 1200, 1230, and 1330 at site 4.

While collecting the air and water vapor samples for tritium, a Kurz high-volume particulate sampler was operated at site 4 between 1114 and 1400. The average air flow, measured with a calibrated minihelic gauge was 50.0 cfm (1.42 m^3/min.). During this sampling period (166.6 min.), particulates were collected on a 4-in. MSA dust filter from a total volume of 236 m^3. A similar sampler was operated continuously at site 11 (see Fig. 3.3) from 1255 on December 14 to 1136 on December 16 (2799 minutes). This was considered the background particulate sample. A total volume of 3171 m^3 was sampled at a rate of 40 cfm (1.13 m^3/min.).

External gamma-ray measurements were made one meter aboveground at each site using a Ludlum Model 12S Micro R Meter. Exposure rates measured were as follows:

Site 1 = 4 μR/hr
Site 2 = 5 μR/hr
Site 3 = 10 μR/hr
Site 4 = 6 μR/hr
Site 11 = 4 μR/hr

The increased gamma-ray exposure rate due to the presence of the plume was easily detected at the close site (No. 3). The other measurements were near the background exposure rate of about 5 μR/hr.

3.1.3 Analyses.

The condensed water vapor samples were analyzed directly for tritium by liquid scintillation counting. The gas samples were passed through a system that catalytically oxidized the HT to HTO (G075). The HTO was then collected in a freeze trap and analyzed by liquid scintillation counting.

The MSA air filters were analyzed by Ge(Li) detector systems to measure the concentration of gamma-ray emitters. The filters were then solubilized and analyzed for Sr-90 and isotopes of U, Pu, Am, and Cm. The analytical procedures used are described in the Laboratory's Radiochemical Procedures Manual (Li83) and the analyses adhered to rigid quality assurance procedures (Ea82).

3.1.4 Results and Discussion.

The concentrations of tritium, in the form of HTO, measured in the water vapor collected from the atmosphere are listed in Table 3.1. The tritium was measured as pCi/ml of water. Tritium in the elemental form was not detected in any of the 1.0 liter grab samples collected in the evacuated gas bottles at sites 3 or 4. This was probably a result of the high minimum detectable level, 2000 pCi/m^3, and possibly not being directly in the plume center line at the instant of sample collection. SRP reported that 38 percent of the total tritium discharged was in the form of HT (Ra82).

The average water content of the air during the collection period was reported by the Plant's Meteorology Section to be 4.9 g/m^3. Thus, multiplying the concentrations in the water by the amount of water per m^3 of air gives the airborne concentrations of HTO shown in the fifth column of Table 3.1. The total tritium concentrations that are listed in the last column of Table 3.1 were based upon the measured HTO concentrations and the percentage of the total tritium discharged that was of the oxide form.

The small amount of tritium, 150 pCi/m^3, that was measured in the air at the distant background site (No. 1) was from a source other than the tritium facility (200-H). Tritium was undetectable in the air at the nearby background site (No. 2), which strongly indicates that all tritium measured in the air at sites No. 3 and No. 4 was due to releases from the Tritium Facility. As expected, the concentration in the air at the near site (no. 3) was greater (about 3.5 times) than the concentration at the more distant site (No. 4). This difference is not directly related to plume concentration, because it fails to account for the variation in plume direction and the fraction of the time the samplers were out of the plume. Because of plume dispersion with distance, the sampler at site 4 was probably in the plume a greater percent of the time, but saw a lower tritium concentration. These results will be compared in Section 5 to computed concentrations using AIRDOS-EPA with on-site wind dispersion data.

The concentration of radioactive particulates in the plume that were collected at site 4 in sample SRPP01 are listed in Table 3.2. The only gamma-ray emitting radionuclides measured were traces of Cs-137. The concentration of Be-7, a cosmogenetically produced radionuclide, was near reported background levels (NCRP75), and the background concentrations measured in samples SRPP02 and SRPP04. No uranium (< 0.3 fCi/m^3) nor Sr-89 (< 50 fCi/m^3) were detected, but a trace of plutonium may have been present in the plume. This is not surprising since plutonium is processed in the H-Area.

Table 3.1 Measured concentrations of HTO and computed total concentrations of tritium in the plume of the tritium facility

Site	Time of Collection	Tritium measured as HTO			Total Tritium, pCi/m^3
		pCi/ml	g H_2O/m^3	pCi/m^3	
1	0945-1439	30.4	4.9	150 ± 45	242 ± 53
2	1035-1420	< 12	4.9	< 60	< 100
3	1100-1410	2,500	4.9	12,250 ± 2,400	19,760 ± 2,800
4	1120-1330	700	4.9	3,430 ± 690	5,530 ± 810

Notes:
1) Discharge rate during sampling = 1.54×10^8 µCi/2.16×10^4 sec. = 7.13×10^3 µCi/sec.
2) Chemical form - 62 percent HTO and 38 percent HT.
3) Collections made 12/14/82.
4) Site Nos. 1 and 2 are background.

Table 3.2 The high-volume particulate sampling data and results

Parameter	Sample SRPP01	SRPP02	SRPP03	SRPP04	SRPP05
Site	4	11	6	8	7
Date of Collection	12/14/82	12/14-16/82	12/15/82	12/15/82	12/15/82
Time of Collection	1115-1400	1255-1136	1010-1337	1108-1410	1125-1350
Elapsed time, min	167	2799	206	182	144
Avg. flow rate, cfm	50.0	40.0	47.8	38.6	41.5
Total volume, m^3	236	3171	279	199	169
Be-7, fCi/m^3(a)	180 ± 60	110 ± 20	< 210	140 ± 70	< 300
Co-60, fCi/m^3	< 20	< 3	< 20	< 25	< 30
Sr-90, fCi/m^3(b)	< 15	< 2	< 13	< 18	< 20
Cs-137, fCi/m^3	30 ± 15	< 3	< 20	< 25	< 30
U-234/238, fCi/m^3	< 0.3	0.025 ± 0.010	< 0.3	< 0.3	< 0.3
Pu-238, fCi/m^3	0.15 ± 0.09	< 0.005	< 0.08	< 0.08	< 0.07
Pu-239, fCi/m^3	0.15 ± 0.08	< 0.005	< 0.08	< 0.08	< 0.07

(a) Decay corrected to time of collection.
(b) Unusually high minimum detectable levels of Sr-90 are due to analyzing only a portion of the filters.

3.2 The Reactor Facility

3.2.1 Meteorology and Sampling Sites. The plume from the 60 meter reactor stack was sampled at near ground level from 1015 to 1424 on December 15, 1982, in a similar fashion to that described previously in Section 3.1.1. Data from the P-Area meteorological station was used to estimate real-time plume dispersion characteristics of the reactor plant releases. Standard deviations of plume crosswind (σ_y) and vertical (σ_z) concentrations were obtained identically as described previously. During this period, the meteorology was continuously monitored and the predicted position of the plume was reported regularly at 15-minute intervals.

In addition to the real-time meteorological data, computer-generated plots of plume trajectory were also prepared by the Meteorological Section of SRL and kindly provided to the authors. An example plot for the 15 minute interval ending at 1200 is shown as Figure 3.4, together with the associated table of wind profiles given in Figure 3.5 for all measurements taken at SRP during the same 15 minute interval.

The Savannah River Plant's Tracking Radiological Atmospheric Contaminants (TRAC) vehicle was used to assist in locating the plume and monitor its movement during periods of sample collection. The mobile unit has 12 NaI(Tl) detectors mounted on the roof that are positioned skyward. The position of the plume relative to the mobile van can be determined by the count rates of ~~the~~ THE SETS OF four detectors.

Collections of HTO vapor were made at site No. 6: 1.904 km bearing 291° from the release point and site No. 7: 2.209 km bearing 323° from the release point. In addition, compressed air samples were collected for Ar-41 and Kr-85 analyses at these sites and at site No. 9: 4.495 km bearing 328° from the release. Compressed air samples were also collected at site No. 8: 2.85 km and bearing 120° from the release. During the entire measurement interval, site No. 8 was upwind of the plume and therefore provided a station to represent background concentrations. See Figures 3.3 and 3.4 for the exact locations of these sites.

DATE: 12/15/82 TIME: 11:59:58 AM EST
15 MINUTE-AVERAGED WIND FROM 121. DEG AT 11.0MPH

P AREA

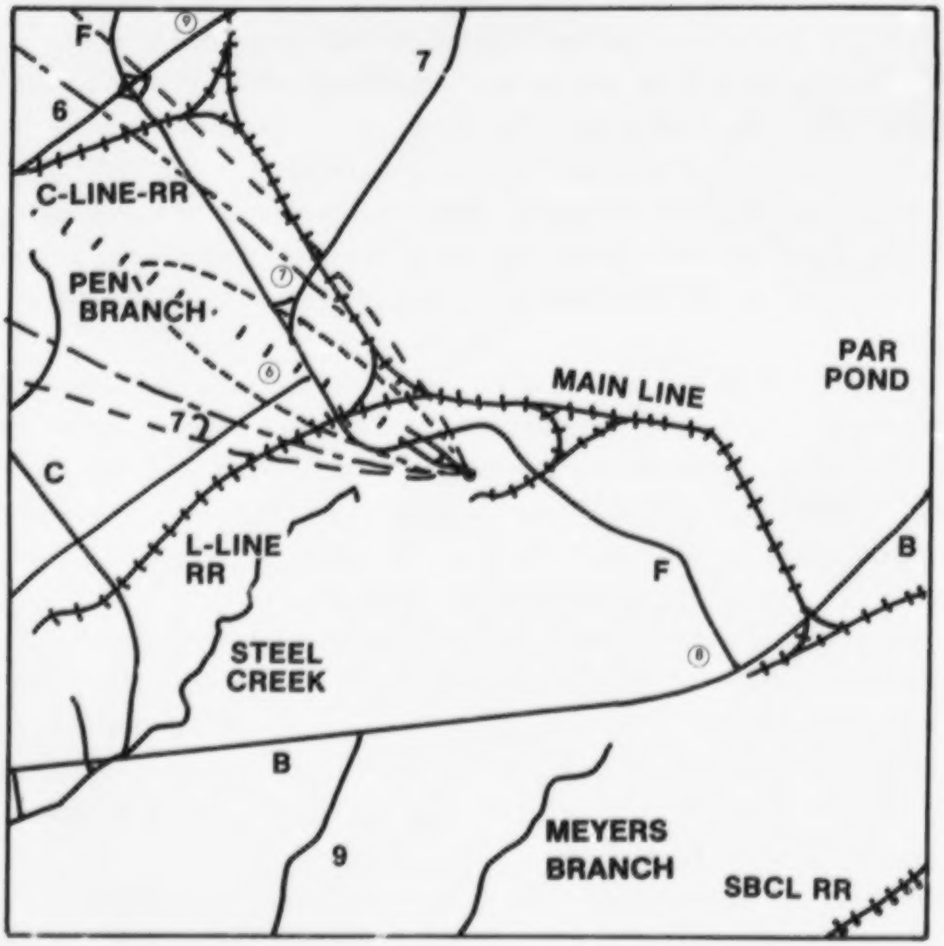
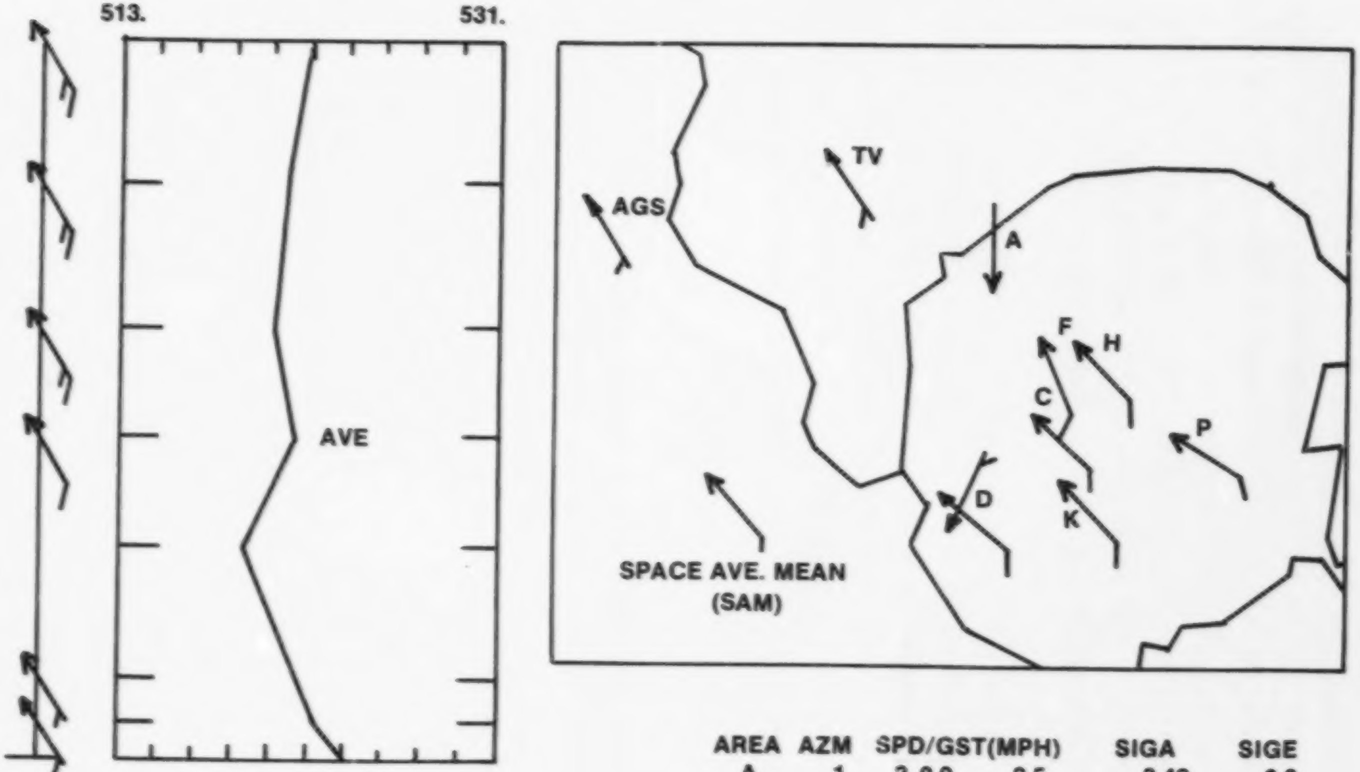

F
⑨
7
6
C-LINE-RR
PEN
BRANCH
⑦
⑥
7
MAIN LINE
PAR
POND
C
L-LINE
RR
F
B
STEEL
CREEK
⑧
B
MEYERS
BRANCH
9
SBCL RR

Fig. 3.4. An example plot of a 15-minute averaged plume profile in P-Area. Sample site numbers are circled. Large letters and numbers designate roads.

14.9 MIN ENDING: 16:59:58 Z 12/15/82 (11:59:58 AM EST 12/15/82)



HT	AZM	SPD/GST(MPH)		SIGA	SIGE	TEMP F
999F	149.	20.4	31.2	8.8	8.0	56.91
800F	151.	15.6	27.1	10.9	10.6	56.93
600F	150.	13.3	21.9	12.6	12.2	57.44
450F	150.	12.4	22.1	13.0	11.0	32.00?
300F	0.	0.0?	0.0?	14.8	14.7	57.62
120F	147.	7.3	17.1	22.6	0.0?	61.18
59F	148.	5.6	12.5	27.5	17.8	62.23
7F						64.16

AREA	AZM	SPD/GST(MPH)		SIGA	SIGE
A	1.	? 0.9	2.5	3.4?	0.3
C	133.	12.6	24.6	13.5	12.3
D1	23.	3.3	11.5	21.4	15.9
D2	131.	9.5	14.1	12.0	9.1
F	158.	12.2	18.5	11.5	9.0
H	137.	12.3	23.5	12.7	11.0
K	136.	10.7	16.3	10.7	9.8
P	121.	11.0	20.2	13.4	10.7
TV	147.	7.3	31.2	18.0	8.6
SAM	137.	10.8	31.2	12.9	10.8
AGS	150.	3.0	(56.0/	49.0	ST:4)

Fig. 3.5. SRP site meteorology for the 15-minute interval ending at 12 PM on December 15, 1982

3.2.2 Sample Collections and Measurements. Air samples were collected from the plume at the locations discussed in Section 3.2.1 using the high pressure gas collection system described in Appendix B (Je80). A background sample was also collected at Site No. 8. Samples were transported immediately after collection to the 700 Area and analyzed as quickly as possible in order to prevent excessive decay of the 1.827 hour Ar-41 (Ko81). The plume samples were collected in series and as often as time permitted.

A Model RSS111 Reuter Stokes, pressurized ionization chamber (PIC) was operated 1-meter aboveground near the compressor throughout the period the high pressure gas samples were being collected. The average net exposure rate (5 μR/hr natural background subtracted) during each of the seven collection periods are listed in Table 3.3. According to the PIC integrator, the average exposure rate during plume sampling exceeded background by 6 μR/hr.

Table 3.3 The average net exposure rate in the plume during collection of the compressed-air samples

Collection site	Collection time		Average net exposure rate, μR/hr
	Start	Stop	
6	1015	1040	6.0
7	1048	1107	4.4
7	1113	1133	8.8
7	1142	1200	6.7
7	1203	1227	6.2
7	1230	1248	5.0
9	1321	1340	4.2
8	1108	1410	0

Notes:
1) Measurements made on 12/15/82.
2) A background exposure rate of 5 μR/hr was subtracted from each PIC measured gross exposure rate.
3) Collection Site No. 8 was the background site.

Water vapor was condensed from the atmosphere at Sites 6 and 7 by pulling air through first a filter to remove particulates and then a cold trap submerged in a dry-ice/alcohol bath. Air flow through the systems was initially about 9 liters/minute, but, due to high humidity, the flow decreased significantly during sampling as large amounts of ice formed in the traps. At the conclusion of the sampling period, the frozen vapor in the traps was allowed to melt and the resultant water transferred to scintillation counting vials for later measurement of the tritium that existed as HTO. During the sampling period, the average temperature and relative humidity were reported by the Meteorology Section to be 18°C and 65 percent, respectively.

To determine the gaseous tritium (HT) concentrations of the plume, air samples were collected by opening 1-liter evacuated gas bottles to the atmosphere and then sealing for laboratory analysis. Samples of this type were collected at 1100 and 1130 at Site 7, and at 1410 at Site 8, the background site.

Kurz high-volume particulate samplers were operated in the plume at Sites 6 and 7 and at Site 8, the background site. The particulate collection data are shown in Table 3.2. The average air flows were measured with a calibrated minihelic gauge. The particulates were collected on a 4-in. diameter MSA dust filter. The collection data for the long-term background sample from Site 11 is included in Table 3.2.

3.2.3 Analyses. The airborne concentrations of Ar-41 were measured with the specialized detector-spectrometer system described in Appendix B (Je80). Samples were analyzed for 30 minutes, and the concentrations of Ar-41 measured were corrected for radioactive decay to the mid-time of the sample collection period. The sample chamber was flushed with P-10 gas between each analysis.

Five hundred liters to a cubic meter of the gas collected in scuba bottles were transferred to the laboratory for Kr-85 analyses. The Kr-85 was separated from other gases by a cryogenic technique and transferred to scintillation vials containing a liquid scintillator (St71). The Kr-85 was then measured by liquid scintillation counting.

The condensed water vapor samples were analyzed directly for tritium by liquid scintillation counting. The gas samples were passed through a system that catalytically oxidized the HT to HTO (Go75). The HTO was then collected in a freeze trap and analyzed by liquid scintillation counting.

The MSA air filters were analyzed by Ge(Li) detector systems to measure the concentration of gamma-ray emitters. The filters were then solubilized and analyzed for Sr-90 and isotopes of U, Pu, Am, and Cm. The analytical procedures used are described in the EERF's Radiochemistry Procedures Manual (Li83), and the analyses adhered to rigid quality assurance procedures (Ea82).

3.2.4 Results and Discussion. The concentrations of Ar-41 that were measured in the air collected in the plume from the reactor stack are listed in Table 3.4. The concentrations varied from less than 600 pCi/m^3 to over 2,000 pCi/m^3. This variation was due to movement of the plume with respect to the collection apparatus during sampling. During the first sampling period, 1015-1040, the plume was slowly moving to a more northernly direction. During the next 5 collection periods, 1048-1248, the plume slowly drifted back and forth over the stationary collection apparatus at site 7. The lower Ar-41 concentration measured at site 9 was due to an increased distance from the source and directional variation of the plume during sampling.

The average net pressurized ionization chamber (PIC) measurements listed in Table 3.3 are compared in Figure 3.6 to the Ar-41 concentrations measured in the plume during the same time periods. The Ar-41 concentrations and exposure rates followed the same general trends. A close relationship between the two independent measurements was not expected, because the PIC measurements respond to other radioactive components of the plume in addition to Ar-41. But the PIC did detect the presence of the plume and measured the external radiation exposure resulting from the plume's presence at that particular location.

Table 3.4 Measured concentrations of Ar-41 in the plume from P-reactor

Collection Site	Collection period Start	Collection period Stop	Ar-41, pCi/m^3
6	1015	1040	1660 ± 500
7	1048	1107	270 ± 380
7	1113	1133	2340 ± 750
7	1142	1200	1810 ± 740
7	1203	1227	440 ± 630
7	1230	1248	430 ± 700
8	1404	1424	≤ 640
9	1321	1340	300 ± 650

Notes:
1) Samples collected on 12/15/82.
2) Concentrations of Ar-41 corrected for decay to the midpoint ofcollection period.
3) The ± values given are 2-sigma counting errors.
4) See Appendix B for detailed sample collection and counting data.

The Ar-41 plume measurements are compared in Figure 3.7 to the TRAC Plume Monitor counts for each sampling period. The data used to make this comparison are given in Appendix C and summarized in Table 3.5. The 60 second counts from the two rear quadrants of the Monitor, Sectors III and IV, were averaged for each sampling period. The average net count rates (average cpm less background), for each period are listed in the third column of Table 3.5. The data from the rear quadrants were used in the comparison because the compressor was operated about 25 m to the rear of the TRAC Mobile Laboratory.

The similar shape of the two curves in Figure 3.7 shows that a correlation exists between the counts recorded by the plume monitor and the measured Ar-41 concentrations. Statistically significant Ar-41 concentrations were measured for periods III and IV, whereas, the concentrations measured

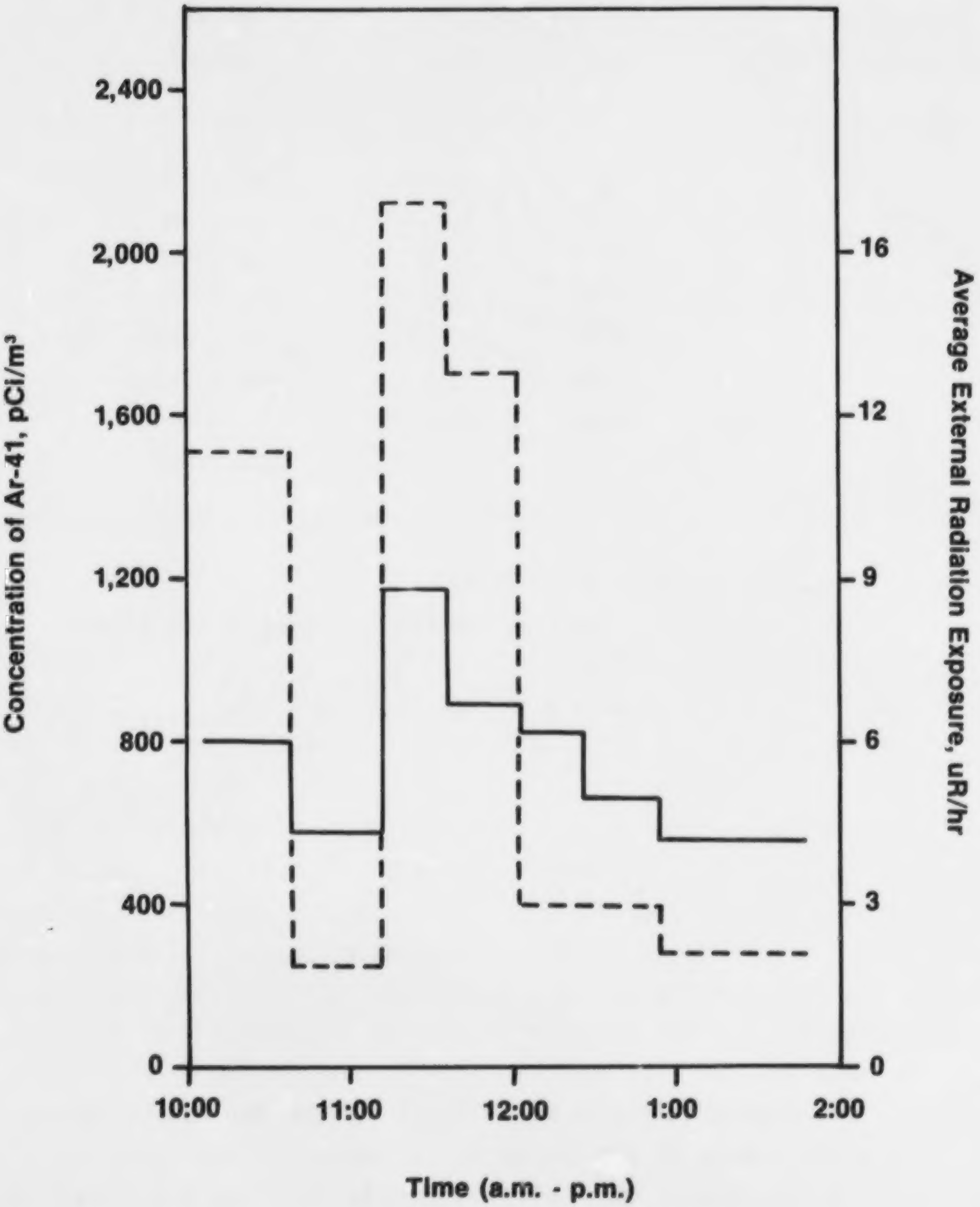


Fig. 3.6. The concentration of argon-41 (---) plotted with the average net external exposure (PIC) from the plume for each sample collection period.

during periods II, V, VI, and VII were not statistically significant because too long of decay periods were permitted between sample collections and analyses (see Appendix B). Concentrations of Ar-41 for these periods were estimated by using the average Ar-41 (pCi/m^3) to CPM ratio for the periods III and IV, computed to be 0.72. Multiplying this ratio by the average cpm value for the period yields the estimated Ar-41 concentrations listed in the last column of Table 3.5. These results will be further discussed in Section 5.

Table 3.5 A summary of the Mobile Plume Monitoring data for each collection period with the corresponding Ar-41 concentration(a)

Sampling Period	Collection Time (b)	TRAC System Net Counts (CPM)(c)	Ar-41,(f) pCi/m^3	Estimated Ar-41, pCi/m^3
I	1015-1040	NR(d)	1660 ± 500	---
II	1048-1107	609 ± 12	270 ± 380	440
III	1113-1133	3082 ± 21	2340 ± 750	(e)
IV	1142-1200	2612 ± 20	1810 ± 740	(e)
V	1203-1227	1477 ± 14	440 ± 630	1060
VI	1230-1248	844 ± 12	430 ± 700	610
VII	1321-1340	442 ± 10	300 ± 650	320
VIII (BKG)	1404-1424	12 ± 2	< 640	---

(a) See Appendix C for the detailed counting data.

(b) All samples were collected on December 15, 1982.

(c) The average net count rate for the detectors in Sectors III and IV for the period indicated.

(d) NR - Not reported.

(e) Results used to determine the average Ar-41/cpm ratio of 0.72, which was applied to the other period data to obtain the estimated Ar-41 concentrations.

(f) Concentrations from Table 3.4.

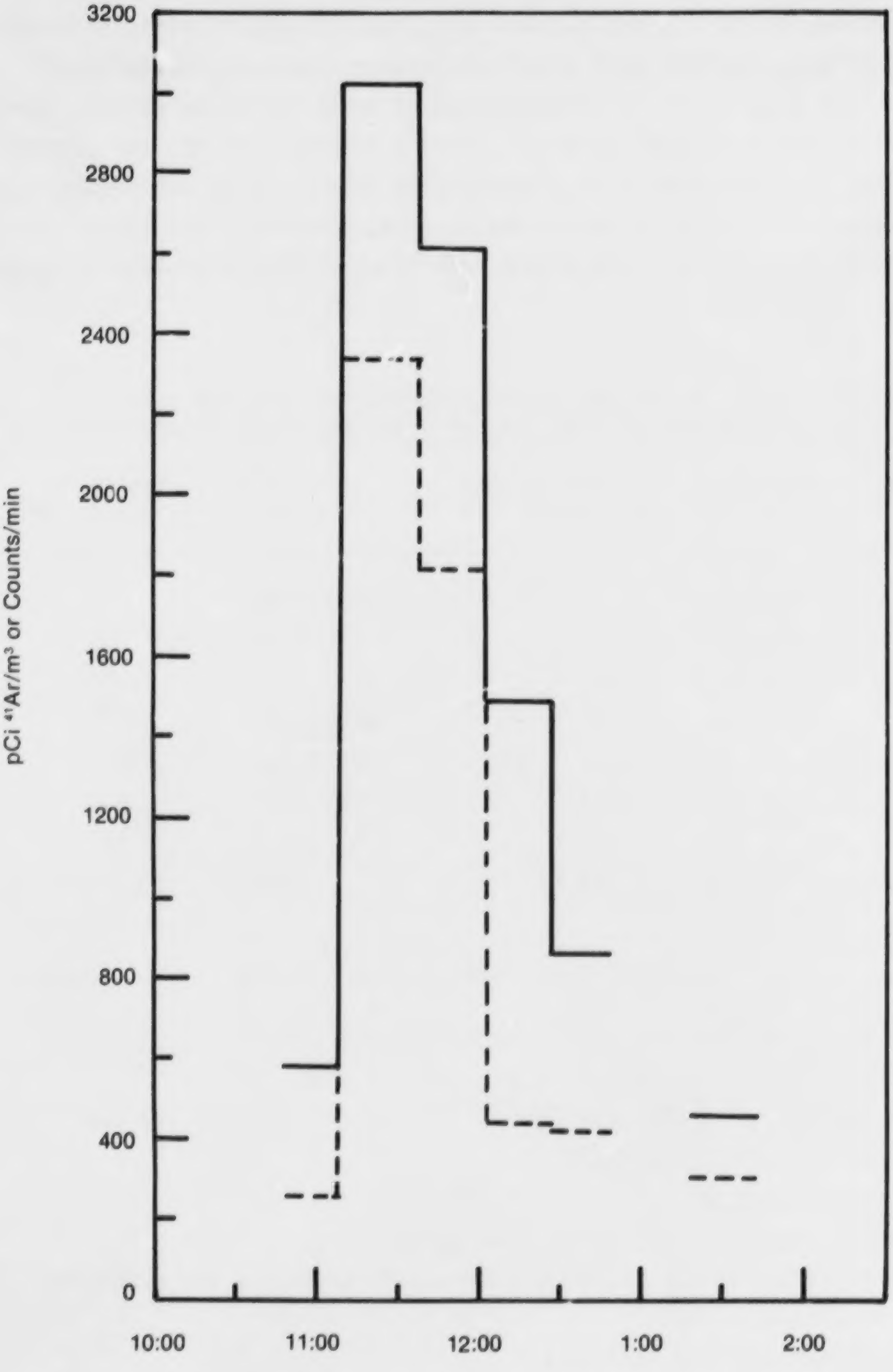


Fig. 3.7. The concentration of argon-41 as pCi/m³ (---) plotted with the average net count rate of the rear two quadrants (counts/minute) of the TRAC Plume Monitor.

Because the Kr-85 concentrations were below the minimum detectable level of the Penn State Noble Gas Monitor (see Appendix B), the compressed air samples were returned to the EERF for cryogenic separation of krypton and analyses by liquid scintillation counting (see Section 3.2.3). However, because of inadequate purging, the scuba tanks contained residual Kr-85 from earlier sampling, thus contaminating the SRP samples. Therefore, Kr-85 measurements were not achieved.

The concentrations of tritium measured in the water vapor collected from the atmosphere at sites 6 and 7 are listed in Table 3.6. Plant personnel reported that all H-3 released from the reactor facilities is in the oxide form (Ra82). Although no elemental tritium was detected in any of the 1-liter grab samples collected, the total absence of elemental tritium could not be confirmed because of the large MDL (2000 pCi/m^3). Site 6 was in the plume for less than half the sampling time indicated in Table 3.6. However, the plume slowly fanned back and forth over the collection trap at site 7 during nearly the entire sampling period

Table 3.6 Measured concentrations of HTO in the plume of the reactor facility

Site	Time of Collection	Tritium concentrations pCi/ml	$g\ H_2O/m^3$	pCi/m^3
6	1020-1230	26	10.0	260 ± 100
7	1130-1345	65	10.0	650 ± 100

Notes: 1) Discharge rate during sampling = 3.0×10^7 pCi/24 hours = 347 μCi/sec (Ra82).

2) Chemical form: 100 percent HTO.

3) Collections made: 12/15/82.

indicated. The collection traps at both sites became frozen during the collection periods. Thus, the airborne H-3 concentration reported is based on the concentration of H-3 in the water collected, and the relative humidity and temperature provided by on-site meteorology. The water content of the atmosphere during collection is also given in Table 3.6.

Collection site 7 was approximately the same distance from the P-reactor stack as was site 4 from the H-Area stacks. Although 20 times more tritium was being discharged from the latter during the respective sampling periods (354 μCi/sec vs 7,130 μCi/sec), the H-3 measured in the plume at site 4 was only 9 times greater than that measured in the plume from P-reactor at site 7. This apparent discrepancy of a factor of 2 may well be explained by differing plume dispersion characteristics and will be considered further in Section 5. The measured environmental airborne concentrations of both H-3 and Ar-41 will be compared in Section 5 to computed concentrations derived from the measured source terms and atmospheric dispersion models.

The concentrations of radioactive particulates measured in the plume are shown in Table 3.2. No particulate radionuclides associated with SRP activities were detected on filters from either site 6 or 7. This indicates efficient control of particulate effluents from the stack and helps to explain the low external gamma-ray exposures measured (see Table 3.3).

3.3 The Chemical Separation Facilities (F and H-Areas)

No reprocessing was being conducted at these facilities during the period of the field study (see Section 2.3). Thus, although stack effluent samples were collected later from one facility when it was again in operation, January 19, 1983, no plume or environmental samples were collected in the area.

4. ENVIRONMENTAL MONITORING

4.1 Sample Collection

4.1.1 Vegetation and Soil Samples. Vegetation samples were collected on Plant property at sampling sites 4, 10, and 11 (see Fig. 3.3). An area of either 1 or 4 m^2 was measured and marked. The vegetation within the area was clipped to near ground-level and bagged. Because of the season, most of the grass collected was not living. A 500 g soil sample was then collected to a depth of 2.0 cm within the area from which the grass had been collected. All roots, rocks, and other debris were removed from the sample.

Sampling site No. 10 was a cultivated field along the northeast side of H Area. The site had been used to grow various food products to study the uptake and transport of plutonium that had been deposited on the site from an earlier H Area discharge. Site 10A was at the south end of the cultivated field nearest the stack. Site 10B was in the approximate center of the field, about 50 m north of 10A. Vegetation at site 4 was collected 10 m west of the tritium and particulate samplers, while grass at site 11 was collected at the 400 D monitoring station.

4.1.2 Food Samples. Foods that can be in the environmental pathways from the Plant to the surrounding populations were sampled at off-site locations. Collards were collected from two locations on 12/15/82; Jackson, S.C. (site 13) and from 7 miles north of Aiken, S.C. (site 12). A sample of beef was collected from a cow butchered on 12/16/82 that had grazed near the intersection of Highways 19 and 302 (site 15). A 1-gallon milk sample was obtained on 12/15/82 in Langley, S.C. (site 14). The locations of these sample collection sites are in a northwesterly direction from the plant site, which has a relatively high joint frequency distribution that approaches about 9 percent (see Fig. 4.1).

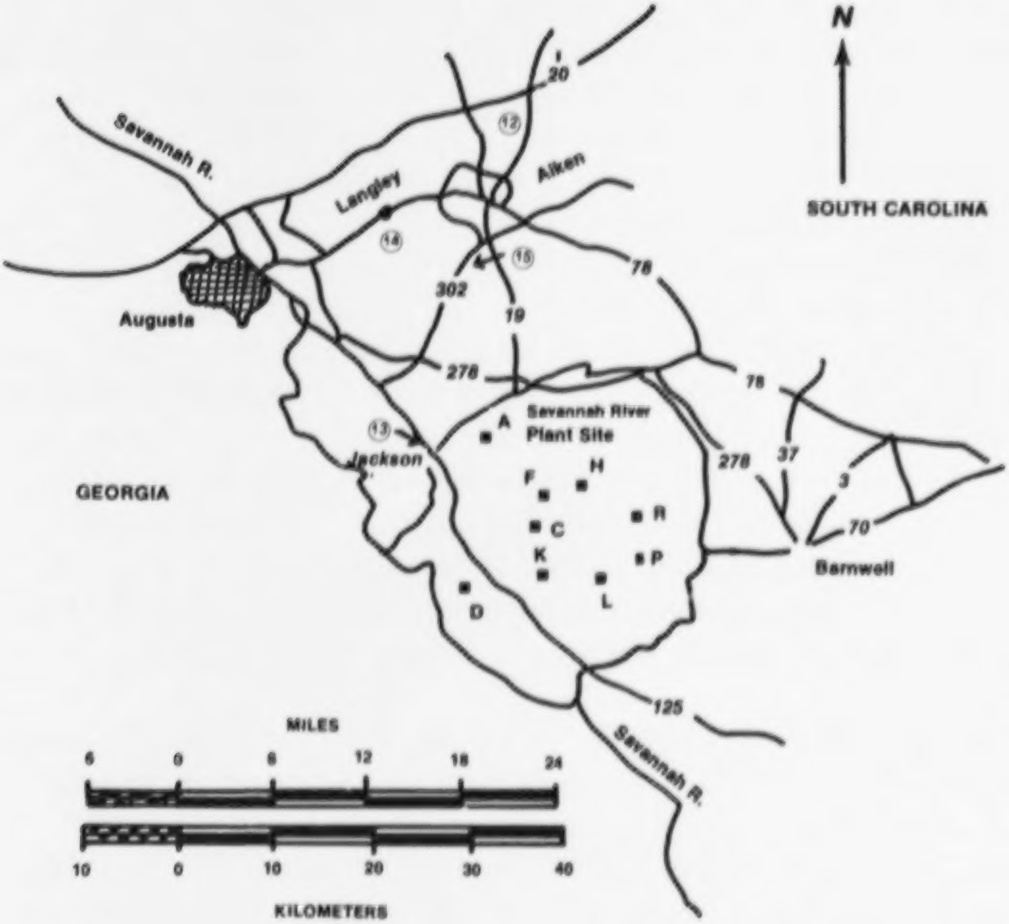

N
SOUTH CAROLINA
I 20
12
Savannah R.
Aiken
Langley
14
15
78
302
19
Augusta
278
78
Savannah River Plant Site
A
13
Jackson
F
H
278
37
3
GEORGIA
C
R
70
K
P
Barnwell
L
D
125
Savannah R.
MILES
6
0
6
12
18
24
10
0
10
20
30
40
KILOMETERS

Fig. 4.1. The Savannah River Plant Site and surrounding area. Sampling locations are outside plant site boundary and are designated by circled numbers with arrows pointing to exact locations. Roads are designated by larger bold numbers. Letters designate site areas.

4.2 Analyses

The grass and collard samples were freeze dried in order to measure the tritium concentration in both the water and fibrous material. The weights of the samples and sample fractions are listed in Table 4.1. The tritium in the water fraction was measured directly by liquid scintillation counting. Both H-3 and C-14 were measured in the fiberous (freeze dried) material by combusting the material and collecting the water and carbon dioxide. The H-3 in the water was again measured by liquid scintillation counting and the C-14 was measured by converting the CO_2 to benzene and counting the C-14 associated with the benzene by liquid scintillation techniques. The concentrations of gamma-ray emitting nuclides in the freeze-dried samples were determined by gamma-ray spectrometry using Ge(Li) detector systems.

The beef sample was also prepared for analyses by freeze drying after being analyzed by gamma-ray spectrometry. The weights of the fractions obtained are listed in Table 4.1. The tritium and carbon-14 concentrations were determined as described above.

Each of the food and environmental samples ~~were~~ was analyzed for Sr-90 and the actinides. This was accomplished by dry ashing the freeze-dried portion of each sample at 1050°F (565°C) for 72 hours, dissolving the ashed sample in acid, and performing the specified radiochemical analysis. The procedures used are described in the EERF's Radiochemistry Procedures Manual (L183).

The soil samples were weighed, dried at 125°C for 24 hours, reweighed, and then ashed for 72 hours at 1050°F (565°C). One gram aliquots of the soil samples were dissolved by treating with HF and acids. Analyses of the dissolved samples were conducted as described in the Procedures Manual.

4.3 Results and Discussion

The tritium concentrations in the grass and food samples are listed in Table 4.2. There were measurable concentrations of H-3 in all samples.

Table 4.1 Weights of environmental and food samples analyzed

Sample	Sample No.	Collection[a] Site	Fresh wt., g	Freeze dried wt., g	Water Collected, ml	Percent Water
Collards	SRVL01	12	1687.4	233.4	1390	86
Collards	SRVL02	13	1183.1	160.5	1020	86
Grass	SRVP01	4	179	122.5	50	32
Grass	SRVP02	10A	610	256	325	58
Grass	SRVP03	10B	480.2	183.8	300	62
Grass	SRVP04	11	315.4	186.6	138	41
Beef	SRBF01	15	389.7	130.9	240	66

(a) See Figures 3.3 and 4.1 for site locations.

Table 4.2 The tritium concentrations in vegetation and food samples

Site	Sample Type	Tritium in 1.0 kg of fresh sample, nCi		
		H-3 in Water	Bound H-3	Total Tritium
			On-Site Samples	
4	Grass	43 ± 2	27 ± 3	70 ± 4
10A	Grass	2090 ± 80	146 ± 15	2240 ± 80
10B	Grass	53 ± 3	47 ± 5	100 ± 6
11	Grass	5.0 ± 0.2	7.7 ± 0.9	13 ± 1
			Off-Site Samples	
12	Collards	0.51 ± 0.17	0.17 ± 0.02	0.7 ± 0.2
13	Collards	9.5 ± 0.4	0.95 ± 0.10	10 ± 1
15	Beef	0.6 ± 0.2	0.5 ± 0.2	1.1 ± 0.5
14	Milk	1.4 ± 0.2	ND	

Note: ND - Not determined.

The higher concentrations occur in the grass samples collected near H-Area; sites 4 and 10 relative to site 11 (see Fig. 3.3). The cause of the significantly higher concentration in the grass from site 10A as opposed to 10B is difficult to explain. A species difference as well as a difference of 500 m distance from the stacks may partly explain the twentyfold concentration difference. In general, more tritium was associated with the plant water than the fibers, however, the winterized condition of the grass probably affected the plant water content and, thus, the quantity of tritiated water. Also, a few percent of the water of combustion may have been inadvertently lost during combustion of the dried fibrous material, which would tend to lower the amount of bound tritium measured in the plant. Thus, there are some uncertainties in these reported concentrations, but not of a nature to account for the wide differences noted.

Elevated levels of tritium were also measured in the off-site food samples, which decreased with distance from the tritium producing areas within the plant boundaries. The tritium concentration in the collards sample collected near the site boundary at Jackson, site 13, was ten times the H-3 concentration in a similar sample collected about 11 km north of Aiken, S.C. The tritium in a sample of beef muscle that had been pastured about 15 km north of the site boundary (site 15) was equally distributed between the water and dried portions, and totaled about 1 nCi/kg fresh weight. The water fraction of the milk sample from Langley contained about 1.5 nCi/l of tritium. Thus, all environmental samples collected from the vicinity of the SRP contained measurable amounts of H-3.

The radionuclide concentrations measured in the vegetation and soil samples, except for H-3, are listed in Table 4.3. No significant concentrations of gamma-ray emitting radionuclides were detected in either the vegetation or soil samples. There was possibly a trace of Co-60 and a somewhat elevated concentration of ^{137}Cs in the grass sample from site 4, the more centrally located sampling location. However, in general, the concentrations measured fall within the expected range of the natural background. Potassium-40 is naturally occurring, Be-7, the most abundant gamma-ray emitter observed in the vegetation, is cosmogenically produced, and Cs-137 is primarily a fallout radionuclide that is readily absorbed by certain plant species (Po67). Thorium-232 and Ra-226 were found to be in the normal background range of 1 to 2 pCi/g (NCRP75).

The specific activity of C-14 is not greatly different in the four grass samples. The average concentration is 18.8 ± 1.2 dpm/g carbon, which is only slightly higher (13 percent) and well within the uncertainty of the natural specific activity reported by Eisenbud (1973), 7.5 ± 2.7 pCi/g C or 16.6 ± 6.0 dpm/g C. The NCRP (1975) reports the specific activity to be 13.5 dpm/g C. The latter is a worldwide value taken from UNSCEAR (Un77) and is lower than values reported by other authors (Ei73, ORP73, Fr64). Therefore, considering the concentrations of C-14 measured and the fact that they did not decrease with distance from the site indicates that most of the C-14 observed was naturally (cosmogenetically) produced with possibly a small contribution from Plant discharges.

Table 4.3 Radionuclide concentrations measured in vegetation and soil samples on site

					Radionuclide concentration	
Site$^{(a)}$	Date	Collection Area, m^2	Total veg. sample, kg	Analyses	vegetation, pCi/kg fresh	Soil, pCi/g dry
4	12/14/82	4	0.18	Be-7	4,100 ± 500	0.14 ± 0.11
				K-40	1,900 ± 700	0.98 ± 0.18
				Co-60	50 ± 40	< 0.05
				Cs-137	810 ± 80	1.76 ± 0.05
				C-14$^{(a)}$	19.6 ± 1.5	NM
				Sr-90	870 ± 50	< 0.23
				Pu-238	3.2 ± 1.0	< 0.03
				Pu-239	4.1 ± 1.2	0.04 ± 0.02
				U-234	17 ± 3	0.67 ± 0.10
				U-238	17 ± 3	0.70 ± 0.10
10A	12/16/82	4	0.61	Be-7	2,300 ± 300	< 0.2
				K-40	1,500 ± 600	3.6 ± 0.2
				Cs-137	420 ± 60	0.54 ± 0.03
				Ru-106	< 60	0.11 ± 0.06
				C-14$^{(a)}$	18.0 ± 1.4	NM
				Sr-90	210 ± 30	< 0.10
				Pu-238	4.3 ± 1.0	0.67 ± 0.14
				Pu-239	7.5 ± 1.5	2.2 ± 0.4
				U-234	7.7 ± 1.4	0.89 ± 0.15
				U-238	5.6 ± 1.1	0.89 ± 0.15
10B	12/16/82	1	0.66	Be-7	2,700 ± 400	< 0.2
				K-40	1,700 ± 500	1.08 ± 0.16
				Cs-137	460 ± 60	0.49 ± 0.03
				C-14$^{(a)}$	20.1 ± 1.6	NM
				Sr-90	180 ± 20	< 0.15
				Pu-238	9.3 ± 1.7	0.35 ± 0.08
				Pu-239	14.7 ± 2.3	1.4 ± 0.2
				U-234	32 ± 4	1.00 ± 0.13
				U-238	32 ± 4	1.00 ± 0.13

Table 4.3 (Continued)

					Radionuclide concentration	
Site(a)	Date	Collection Area, m^2	Total veg. sample, kg	Analyses	vegetation, pCi/kg fresh	Soil, pCi/g dry
11 (Bkgnd)(b)	12/16/82	1	0.32	Be-7	3,400 ± 700	< 0.2
				K-40	2,100 ± 900	2.0 ± 0.4
				Cs-137	130 ± 50	1.79 ± 0.07
				C-14(a)	17.7 ± 1.4	NM
				Sr-90	490 ± 50	< 0.22
				Pu-238	< 0.7	< 0.04
				Pu-239	0.7 ± 0.5	< 0.04
				U-234	13 ± 2	0.45 ± 0.12
				U-238	12 ± 2	0.21 ± 0.07

Notes:
1) See Figure 3.3 for site locations.
2) Tritium concentrations are listed in Table 4.2.
3) NM - Not measured.
(a) Concentrations of C-14 are presented as dpm/g Carbon.
(b) Background site for airborne effluents during collection periods.

The most predominant radionuclides, other than tritium, occurring in the grass samples as a result of Plant operations were Sr-90 at site No. 4, U-234/238 at all sites, and Pu-238/239 at all sites except No. 11 (Table 4.3). No Sr-89 was detected in any environmental samples. Also, Am-241 and Cm-242 were not observed (< 1 pCi/kg). The uranium content of the grass does not appear to reflect soil concentrations and is probably the result of deposition. Levels of uranium in the grass are higher near the H-Area facility and, as in the soil samples, the isotopes are in secular equilibrium. Of the gamma-ray emitters, only Cs-137 concentrations were elevated, primarily at site No. 4 where the soil contained twice the Cs-137 than at other sites. Both Be-7 and K-40 have natural origins. The higher levels of radionuclides associated with site No. 4 are not surprising considering that the site is centrally located, lying between the reactors and the production facilities (see Fig. 3.3).

The plutonium in the soil at sites 10A and 10B and, hence, in the grass is primarily the result of an earlier uncontrolled plutonium release that contaminated the soil at this site. The average gross alpha activity of the soil at this site (~ 28 pCi/g) was about twice that measured at the other two sites (~ 15 pCi/g), which provides further evidence of alpha contamination. The Plant personnel are aware of this condition and have used this area for study of the uptake of plutonium by several agricultural crops. Resuspension of deposited radionuclides poses no problem, due to a perpetual heavy cover of grasses.

The results of the food sample analyses, listed in Table 4.4, do not indicate any gross contamination of the environment beyond the plant boundary. The U-238 concentration in the collards averaged 0.6 ± 0.3 pCi/kg fresh weight and was in equilibrium with U-234. The Sr-90 concentration in the collards grown at site No. 13 is twice that in the plants grown at site No. 12. This difference, like H-3, may reflect plant discharges, considering the closer proximity of site No. 13. However, because natural variation in concentration can also account for this difference, more analyses would be required in order to determine whether plant discharges are the source of Sr-90 in the collards from this site. Strontium-90 in milk and beef are typical of ambient levels. A 1982

Table 4.4 Radionuclide concentrations measured in foods collected near the Savannah River Plant

Food Sample	Site (a)	Collection Date	Analyses(c)	Concentration, pCi/kg or liter
Collards (pCi/kg)	12	12/15/82	K-40	3,900 ± 300
			Cs-137	≤ 30
			C-14(b)	16.5 ± 1.3
			Sr-90	99 ± 14
			Pu-238/239	≤ 0.70
			U-234	0.4 ± 0.2
			U-238	0.5 ± 0.2
Collards (pCi/kg)	13	12/15/82	K-40	5,400 ± 400
			Cs-137	≤ 30
			C-14(b)	16.7 ± 1.3
			Sr-90	190 ± 17
			Pu-238/239	≤ 0.70
			U-234	NR(d)
			U-238	0.8 ± 0.4
Milk (pCi/l)	14	12/15/82	K-40	1,200 ± 200
			Cs-137	≤ 10
			Sr-90	1.8 ± 0.7
			Pu-238/239	≤ 0.7
Beef (pCi/kg)	15	12/16/82	K-40	2,300 ± 200
			Cs-137	17 ± 7
			C-14(b)	18.7 ± 1.5
			Sr-90	5.5 ± 1.2
			Pu-238/239	≤ 0.3

(a) See Figure 4.1 for site locations.
(b) Concentrations of C-14 are presented as dpm/g Carbon.
(c) Tritium concentrations are given in Table 4.2.
(d) NR - Not reported.

composite milk sample from the southeastern states was reported to contain 1.8 ± 0.6 pCi/l of Sr-90 (EPA83), exactly the concentration measured in the milk collected from site No. 14. Strontium-90 levels in meat can vary between 2-10 pCi/kg.

Thus, from the results of these few food type samples that were raised near the site, only H-3 contamination can be linked unequivocally to plant releases. The tritium levels are low and rapidly diminish with distance from the site. The radiation dose equivalent due to tritium was estimated for an individual who raises all foods near the Savannah River Plant. The data used were as follows:

Food	Annual(a) Intake, kg	H-3,(b) nCi/kg	pCi H-3 Intake/yr
Meat	94	1.1	1.03E+5
Milk	112	1.4	1.57E+5
Leafy vegetables	18	10	1.80E+5

(a) Source: EPA79.

(b) Concentrations from Tables 4.2 [redacted]

The total annual intake of tritium, 4.4E+5 pCi/yr, multiplied by the whole-body dose conversion factor, 8.614E-8 mrem/pCi (Du80), yielded a whole-body dose equivalent rate of 0.04 mrem/yr. This dose will cause no significant health impact.

Although not confirmed by measurements, concentrations of C-14 and plutonium may be slightly elevated above ambient levels in food samples collected near the site due to plant releases. Carbon-14 measurements indicate an excess of 1-2 dpm/gC above the natural level. This quantity is equivalent to about 90 pCi/kg vegetables, 70 pCi/kg meat, and 40 pCi/kg milk. Using these concentrations with the annual intake of foods given above and a whole-body dose conversion factor of 1.58E-6 mrem/pCi (Du80), yields a whole-body dose equivalent rate of 0.02 mrem/yr. Plutonium is below the MDL in food type samples grown near the site boundary.

5. MODELING

5.1 Predicted Airborne Concentrations

5.1.1 Results From EPA Modeling (Tritium measurements on 12/14/82). Tritium oxide (HTO) was measured at site No. 3 from 1100 to 1410 and at site No. 4 from 1120 to 1330 as described in Section 3.1.1. Ground level concentrations normalized for source term χ/Q were calculated for each measurement interval. A summary of these calculated and measured χ/Q values are given in Table 5.1 for site No. 3. The azimuth angle of the line drawn from H-Area release point to site No. 3 is 220°. During the sampling interval at site No. 3, the plume azimuth angle varied between 186° (for the 1230 to 1245 meteorology) and 224° (for the 1400 to 1415 meteorology). A visual display of the relative orientation of release, plume, and sampling site is given in Figure 5.1.

The average of the calculated χ/Q values at site No. 3 was 8.7×10^{-7} sec/m^3 compared with a measured value of 2.8×10^{-6} sec/m^3. This results in a ratio of the measured to calculated values of 3.2.

The azimuth angle of the line drawn from the H-Area release point to site No. 4 is 209°. During the sampling interval at site No. 4, the plume azimuth varied between 186° and 213°, thus sweeping over the sampling point during the measurement. The average of the calculated χ/Q values at site No. 4 was 3.2×10^{-7} sec/m^3 compared with a measured value of 7.7×10^{-7} sec/m^3 (see Table 5.2). This results in a ratio of the measured to calculated χ/Q of 2.4.

Argon-41 measurements on 12/15/82. Compressed air samples were taken on 12/15/82 at sites 6, 7, and 9 and analyzed for Ar-41. These measurements were made to examine noble gas releases from P-reactor. Details of the collection intervals and measured Ar-41 concentrations are given in Table 3.4. Ground level air concentrations normalized for source term χ/Q were calculated for each measurement interval.

As previously mentioned in Section 3.2.1, SRP's mobile gamma-ray detection unit (TRAC vehicle) and a mobile PIC were used to verify the

Table 5.1 Calculated and measured χ/Q values for tritium at site No. 3 on 12/14/82

15 minute interval ending	Wind* azimuth	Wind speed mph	Horizontal standard deviation σ_θ	Vertical standard deviation σ_ϕ
1115	15	6.1	18.0	19.3
1130	13	6.0	18.5	14.7
1145	19	6.1	14.7	14.1
1200	12	6.4	19.0	17.2
1215	16	4.5	27.0	25.9
1230	33	5.2	21.1	16.8
1245	6	5.9	17.7	20.0
1300	22	5.2	19.6	17.6
1315	15	3.0	52.7	24.7
1330	12	5.6	25.0	21.7
1345	17	7.0	15.7	12.7
1400	31	5.1	30.5	23.2
1415	44	5.4	27.4	16.8

Calculated			Measured			
Stability class	χ/Q (sec/m^3)	Average χ/Q	Average Concentration (Ci/m^3)	Source Term Q (Ci/sec)	χ/Q (sec/m^3)	Ratio Meas./Calc.
B	1.7×10^{-7}	8.7×10^{-7}	1.98×10^{-8}	7.13×10^{-3}	2.8×10^{-6}	3.2
B	1.0×10^{-7}					
C	2.5×10^{-8}					
B	3.9×10^{-8}					
A	3.3×10^{-7}					
B	5.9×10^{-6}					
B	1.4×10^{-8}					
B	1.1×10^{-6}					
A	4.4×10^{-7}					
A	1.4×10^{-7}					
C	1.1×10^{-8}					
A	1.4×10^{-6}					
A	1.6×10^{-6}					

* Wind azimuth + 180° = plume azimuth (see Fig. 5.1).

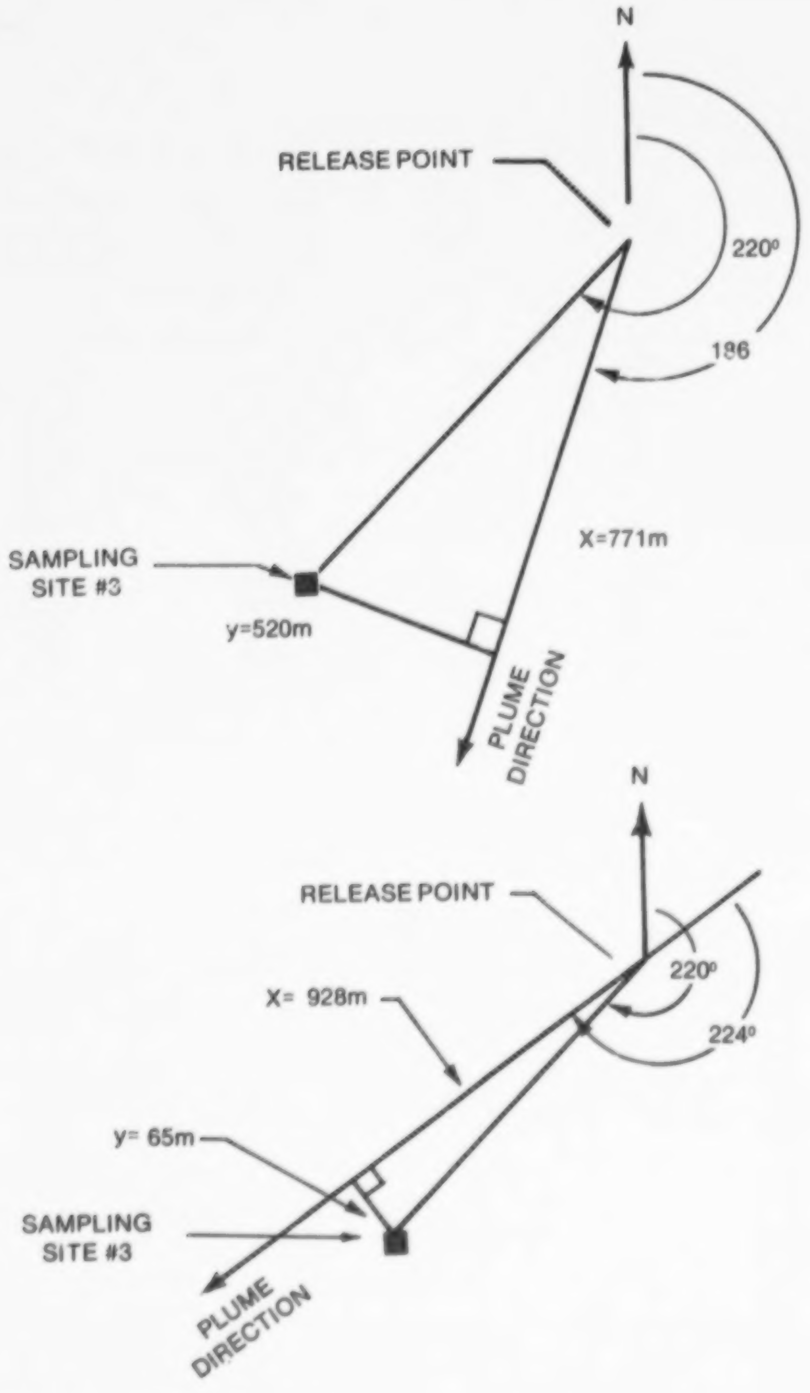

N
RELEASE POINT
220°
186
X=771m
SAMPLING SITE #3
y=520m
PLUME DIRECTION
N
RELEASE POINT
220°
224°
X= 928m
y= 65m
SAMPLING SITE #3
PLUME DIRECTION

Fig. 5.1. Geometry of the plume for two representative tritium measurements from H-Area on December 14, 1982.

Table 5.2 Calculated and measured χ/Q values for tritium at Site No. 4 on 12/14/82

Meteorological Data

15 minute interval ending	Wind azimuth	Wind speed mph	Horizontal standard deviation σ_θ	Vertical standard deviation σ_ϕ
1130	13	6.0	18.5	14.7
1145	19	6.1	14.7	14.1
1200	12	6.4	19.0	17.2
1215	16	4.5	27.0	25.9
1230	33	5.2	21.1	16.8
1245	6	5.9	17.7	20.0
1300	22	5.2	19.6	17.6
1315	15	3.0	52.7	24.7
1330	12	5.6	25.0	21.7

Calculated				Measured			
Stability class		χ/Q (sec/m^3)	Average value χ/Q (sec/m^3)	Average concentration (Ci/m^3)	Source term Q (Ci/sec)	χ/Q (sec/m^3)	Ratio Meas./Calc.
1130	B	1.61×10^{-7}	3.2×10^{-7}	5.5×10^{-9}	7.1×10^{-3}	7.7×10^{-7}	2.4
1145	C	5.73×10^{-7}					
1200	B	$1.2\ \times10^{-7}$					
1215	A	$4.7\ \times10^{-8}$					
1230	B	1.05×10^{-6}					
1245	B	2.42×10^{-8}					
1300	B	8.16×10^{-7}					
1315	A	6.45×10^{-8}					
1330	A	2.29×10^{-8}					

position of the plume during each measurement interval. Use of this instrument during the sampling proved most valuable because it demonstrated that the plume position indicated by the 15-minute averaged wind direction from P-area was not correct. Fortunately, use of this instrument allowed a correction of the tabulated wind azimuth to be made. This correction was made by adding the estimated azimuth error to the tabulated wind azimuth to obtain a corrected value. The correction was obtained as follows:

> The χ/Q measurement during the 11:13-11:33 internal at site No. 7 was found to be 1.9×10^{-6} (see Table 5.3) and corresponded to a tabulated wind azimuth of 295°. However, the true azimuth to site No. 7 is 323°. Both the measured χ/Q and the gamma detection unit verified the presence of the plume over site No. 7 during this measurement interval. This indicates an error in the tabulated plume azimuth for this measurement of (323°-295°) or 28°. Therefore, 28° was taken as the constant error in azimuth angle for all measurements from P-Area. (The magnitude of data taken did not allow the authors to verify the constancy of the azimuth angle error).

This apparent error in wind direction, as obtained from the P-Area meteorological tower, is demonstrated in Figures 5.2 and 5.3, which show uncorrected values for the 15 minute averaged plume azimuth compared with true azimuth to the measurement site. It is evident that the measured winds (arrows) were not in line with the site at which the plume's presence was verified by measurements. Only once did the measured plume direction coincide with the sampling site during the tritium collection period (Fig. 5.2), and not once was there agreement during the argon-41 sampling periods (Fig. 5.3).

The effect of errors in wind direction on estimates of 15 minute averaged χ/Q's can be significant for measurement points within a few kilometers of the release point. The calculated χ/Q is strongly dependent on the off center line distance y:

$$\chi/Q = K \exp -\left[\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right].$$

Table 5.3 Argon-41 measurements at sites 6, 7, and 9 on 12/15/82

Meteorological Data

15 minute interval ending	Wind azimuth, (corrected)	Wind speed mph	Horizontal standard deviation σ_θ	Vertical standard deviation σ_ϕ
Site No. 6 (10:15-10:40 measurement)				
1030	134	8.8	12.6	9.7
1045	139	9.8	9.8	7.8
Site No. 7 (10:48-11:07 measurement)				
1100	135	7.0	13.6	10.2
1115	141	8.9	13.0	10.1
Site No. 7 (11:13-11:33 measurement)				
1130	143	9.6	12.3	9.7
Site No. 7 (11:42-12:00 measurement)				
1200	149	11.0	13.4	10.7
Site No. 7 (12:03-12:27 measurement)				
1215	147	9.6	13.8	10.7
1230	153	9.7	17.5	12.2
Site No. 7 (12:30-12:48 measurement)				
1245	152	12.2	15.9	12.2
Site No. 9 (13:21-13:40 measurement)				
1330	157	10.9	15.0	12.0
1345	163	11.5	15.3	12.2

Table 5.3(Continued)

Calculated				Measured			
15 Minute interval ending	Stability class	χ/Q (sec/m^3)	Average χ/Q	Average concentration (Ci/m^3)	Source term Q(Ci/sec)	χ/Q (sec/m^3)	Ratio Meas./Calc.
Site No. 6 (10:15-10:40 measurement)							
1030	C	1.4×10^{-7}	1.8×10^{-7}	1.7×10^{-9}	1.23×10^{-3}	1.4×10^{-6}	7.9
1045	D	2.1×10^{-7}					
Site No. 7 (10:48-11:07 measurement)							
1100	C	1.2×10^{-6}	1.8×10^{-6}	2.7×10^{-10}	1.23×10^{-3}	2.2×10^{-7}	0.12
1115	C	2.4×10^{-6}					
Site No. 7 (11:13-11:33 measurement)							
1130	D	5.2×10^{-6}	5.2×10^{-6}	2.3×10^{-9}	1.23×10^{-3}	1.9×10^{-6}	0.36
Site No. 7 (11:42-12:00 measurement)							
1200	C	1.2×10^{-6}	1.2×10^{-6}	1.8×10^{-9}	1.23×10^{-3}	1.46×10^{-6}	1.22
Site No. 7 (12:03-12:27 measurement)							
1215	C	1.9×10^{-6}	1.2×10^{-6}	4.4×10^{-10}	1.23×10^{-3}	3.6×10^{-7}	0.30
1230	C	5.1×10^{-7}					
Site No. 7 (12:30-12:48 measurement)							
1245	C	5.4×10^{-7}	5.4×10^{-7}	4.3×10^{-10}	1.23×10^{-3}	3.5×10^{-7}	0.65
Site No. 9 (13:21-13:40 measurement)							
1330	C	1.5×10^{-7}	8.1×10^{-8}	2.95×10^{-10}	1.23×10^{-3}	2.4×10^{-7}	3.0
1345	C	1.1×10^{-8}					

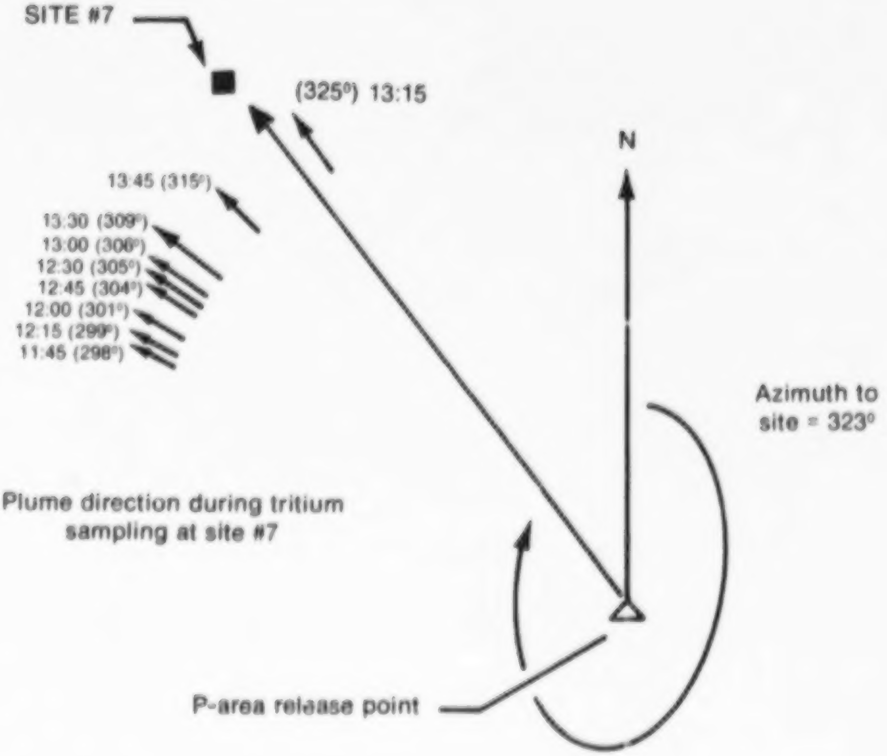

SITE #7
(325°) 13:15
N
13:45 (315°)
13:30 (309°)
13:00 (306°)
12:30 (305°)
12:45 (304°)
12:00 (301°)
12:15 (299°)
11:45 (298°)
Azimuth to
site = 323°
Plume direction during tritium
sampling at site #7
P-area release point

Fig. 5.2. Schematic layout of release from P-Area and the measurement of tritium at Site 7 on December 15, 1982.

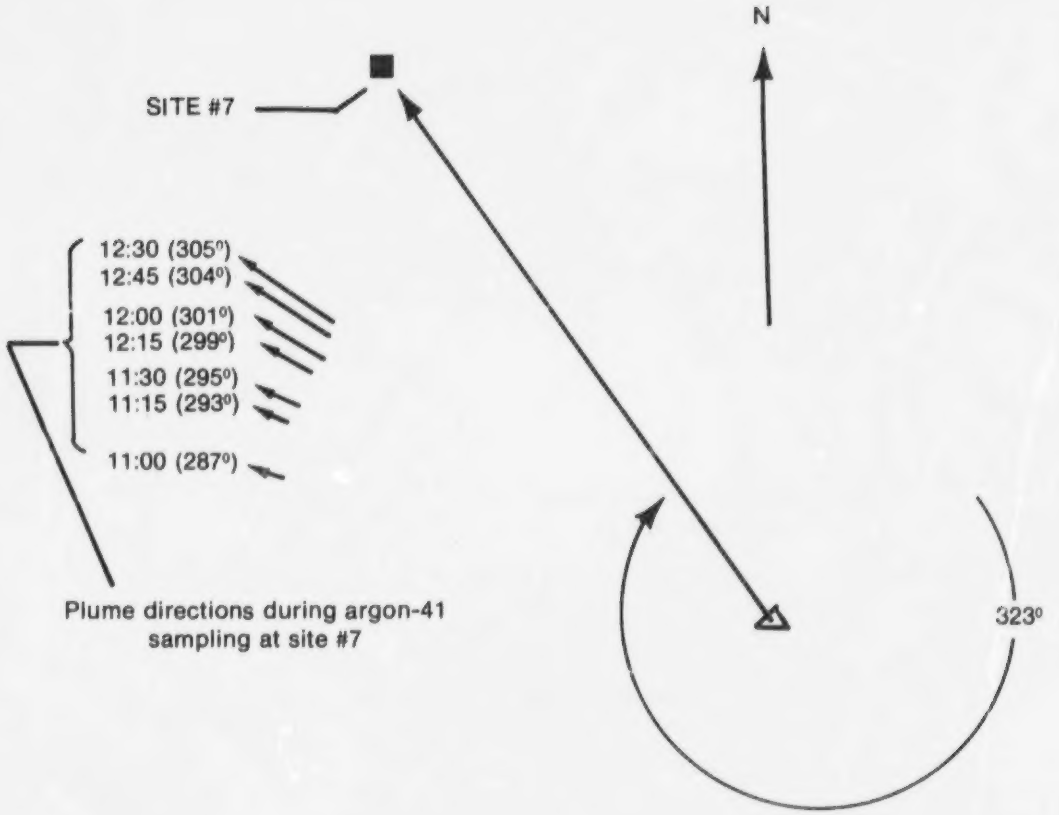

N
SITE #7
12:30 (305°)
12:45 (304°)
12:00 (301°)
12:15 (299°)
11:30 (295°)
11:15 (293°)
11:00 (287°)
Plume directions during argon-41 sampling at site #7
323°

Fig. 5.3. Schematic layout of release from P-Area and the measurement of argon-41 at Site 7 on December 15, 1982.

Therefore, as y increases slightly, calculated χ/Q decreases rapidly. An example for the case of site No. 7 makes this point clear.

Consider the calculation of χ/Q for Ar-41 during the 11:15-11:30 interval. For measured conditions at this point, a plume center line χ/Q is 5.2×10^{-6} sec/m^3, whereas at 5° off center line the calculated concentration is 2.2×10^{-6} sec/m^3, and at 10° off center line the concentration drops to 1.6×10^{-7} sec/m^3. This behavior, shown in Figure 5.4, indicates that the calculated plume concentration is approximately reduced to half the center line value for a deviation in plume direction of about 5°.

Results of calculated and measured χ/Q values for Ar-41 are given in Table 5.3. The azimuth angle of the line drawn from the P-area release point to site No. 6 is 291°. During the sampling interval at site No. 6, the plume azimuth (corrected as described above) varied between 314° and 319°. The average of the two calculated χ/Q values at site No. 6 was 1.8×10^{-7} sec/m^3 compared with a measured value of 1.4×10^{-6} sec/m^3. This yields a ratio of measured to calculated χ/Q of 7.8.

Five separate gas measurements were made at site No. 7 for Ar-41 (Table 3.4). The azimuth angle from the P-area release to site No. 7 was 323°. The plume azimuths (corrected) were as follows: first measurement, 315° and 321°; second measurement, 323°; third measurement, 329°; fourth measurement, 327° and 333°; and the fifth measurement, 332°.

One measurement of χ/Q was made at site No. 9 during the interval 13:21-13:40. The true azimuth to site No. 9 was 328°. During the sampling interval, the plume varied from 337° to 343°. The average value of calculated χ/Q at site No. 9 was 8.1×10^{-8} compared with a measured value of 2.4×10^{-7}. This yields a ratio of measured to calculated χ/Q of 3.0.

Tritium Measurements on 12/15/82. Tritium oxide was also measured downwind of the reactor facility at site No. 6 from 1020 to 1230 and at site No. 7 from 1130 to 1345 (see Table 3.6 for a description of these measurements). Similar to the previous case for argon collection, ground level tritium concentrations normalized for source term were calculated for each

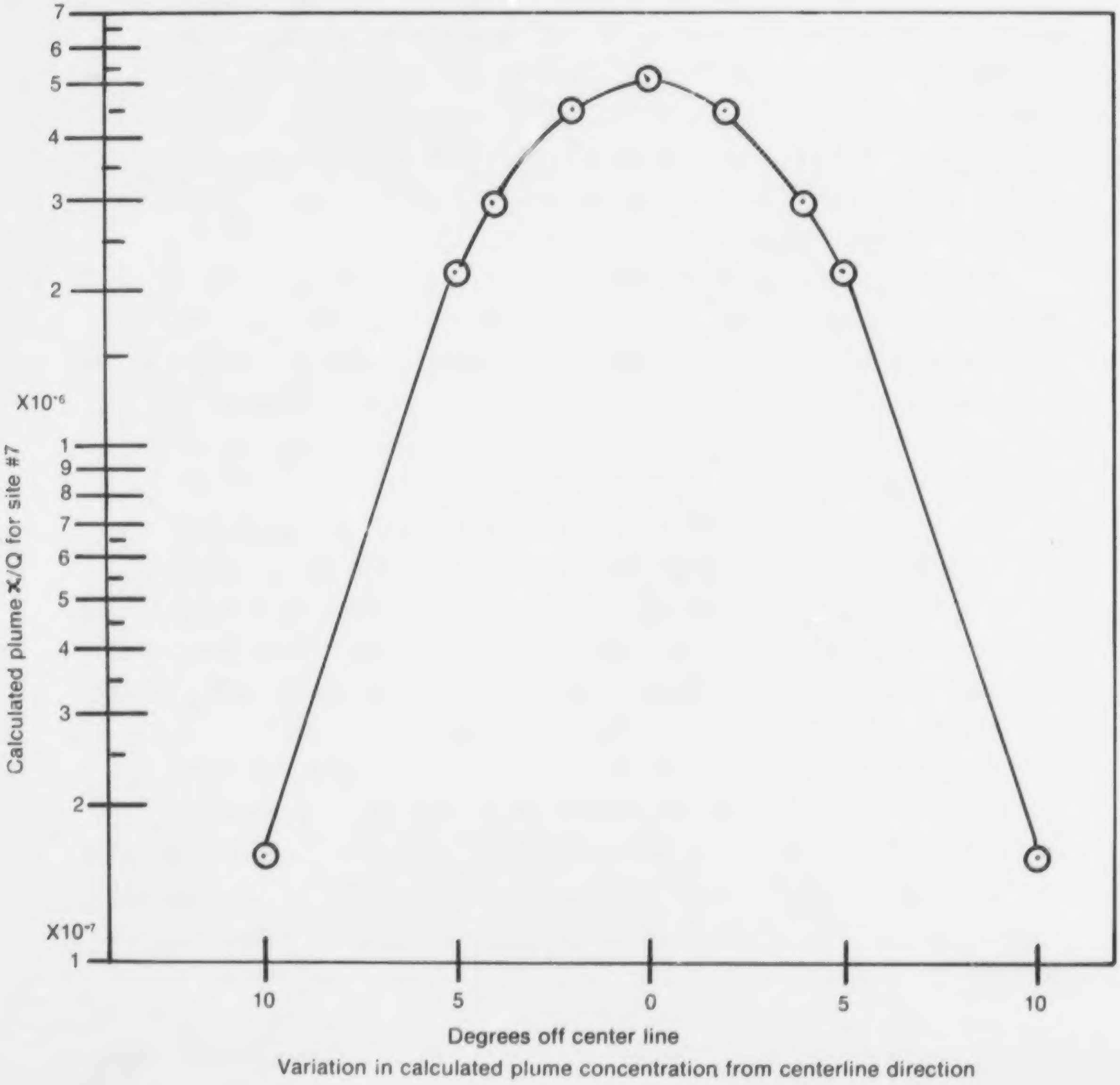


Fig. 5.4. The variation in calculated plume concentration vs. the angle from center line direction for Site 7 on December 15, 1982.

measurement interval. A summary of these calculated and measured χ/Q values are given in Table 5.4 for site No. 6. The azimuth angle of the line drawn from the P-area release point to site No. 6 is 291°. During the sampling interval at site No. 6, the plume azimuth (corrected as described previously) varied between 314° and 333°.

The average of the calculated χ/Q values at site No. 6 was 1.2×10^{-7} sec/m^3 compared with a measured value of 7.5×10^{-7} sec/m^3. This implies a ratio of measured to calculated values of 6.3.

A summary of the calculated and measured χ/Q values are given in Table 5.5 for site No. 7. The azimuth angle of the line drawn from the P-area release point to site No. 7 is 323°. During the sampling interval at site No. 7, the plume azimuth varied between 326° and 353°.

The average of the calculated χ/Q values at site No. 7 was 7.4×10^{-7} sec/m^3 compared with a measured value of 1.9×10^{-6} sec/m^3. This implies a ratio of measured to calculated values of 2.6.

5.1.2 Results From DOE Modeling.* On December 14 and 15, 1983, representatives of the U.S. Environmental Protection Agency (EPA) visited the Savannah River Plant (SRP) to conduct independent measurements of radionuclide concentrations in plumes emitted from SRP production areas. The SRP assisted the EPA in this work. In particular, the Environmental Sciences Division (ESD) of the Savannah River Laboratory (SRL) helped the EPA position its samplers in the correct downwind trajectory forecasts and real-time monitoring of the Ar-41 plume with the TRAC vehicle. The ESD also gave the EPA representatives the meteorological data they needed to test their own diffusion models.

The monitoring period on December 14 lasted from 1100 to 1410 EST. During this period, the winds and turbulence were nearly steady, except for small shifts in wind direction (15 to 20°) near the beginning and end of the observation period. The emission rate of tritium from H-Area was estimated to be 7.1×10^{-3} Ci/s from daily average measurements. Since only the average emissions and sampler data for the entire monitoring

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* This section is presented as prepared by the SRL.

Table 5.4 Calculated and measured χ/Q values for tritium at site No. 6 on 12/15/82

Meteorological Data

15 minute interval ending	Wind azimuth, (corrected*)	Wind speed mph	Horizontal standard deviation σ_θ	Vertical standard deviation σ_ϕ
1030	134	8.8	12.6	9.7
1045	139	9.8	9.8	7.8
1100	135	7.0	13.6	10.2
1115	141	8.9	13.0	10.1
1130	143	9.6	12.3	9.7
1145	146	9.2	14.6	10.2
1200	149	11.0	13.4	10.7
1215	147	9.6	13.8	10.7
1230	153	9.7	17.5	12.2

Calculated			Measured			
Stability class	χ/Q (sec/m^3)	Average χ/Q	Average concentration (Ci/m^3)	Source term Q (Ci/sec)	χ/Q (sec/m^3)	Ratio Meas./Calc.
1030 C	1.4×10^{-7}	1.2×10^{-7}	2.6×10^{-10}	3.5×10^{-4}	7.5×10^{-7}	6.3
1045 D	2.1×10^{-7}					
1100 C	1.7×10^{-7}					
1115 C	1.1×10^{-7}					
1130 D	1.4×10^{-7}					
1145 C	8.3×10^{-8}					
1200 C	5.9×10^{-8}					
1215 C	7.5×10^{-8}					
1230 C	5.4×10^{-8}					

* See discussion of wind azimuth correction in Section 5.1.1.

Table 5.5 Calculated and measured χ/Q values for tritium at site No. 7 on 12/15/82

Meteorological Data

15 minute interval ending	Wind azimuth, (corrected*)	Wind speed mph	Horizontal standard deviation σ_θ	Vertical standard deviation σ_ϕ
1145	146	9.2	14.6	10.2
1200	149	11.0	13.4	10.7
1215	147	9.6	13.8	10.7
1230	153	9.7	17.5	12.2
1245	152	12.2	15.9	12.1
1300	154	15.6	12.9	9.0
1315	173	13.2	13.0	7.0
1330	157	10.9	15.0	12.0
1345	163	11.5	15.3	12.2

Calculated				Measured			
	Stability class	χ/Q (sec/m^3)	Average χ/Q	Average concentration (Ci/m^3)	Source term Q (Ci/sec)	χ/Q (sec/m^3)	Ratio Meas./Calc.
1145	C	2.2×10^{-6}	7.4×10^{-7}	6.5×10^{-10}	3.5×10^{-4}	1.9×10^{-6}	2.6
1200	C	1.2×10^{-6}					
1215	C	1.9×10^{-6}					
1230	C	5.1×10^{-7}					
1245	C	5.4×10^{-7}					
1300	C	2.3×10^{-7}					
1315	C	5.8×10^{-12}					
1330	C	1.1×10^{-7}					
1345	C	6.0×10^{-9}					

* See discussion of wind azimuth correction in Section 5.1.1.

period were provided, and the winds were steady, ESD made one calculation of the plume concentrations. Winds and turbulence were also fairly steady on December 15, when Ar-41 and tritium plumes from the P-Area reactor were measured. The emission rate for Ar-41 was 1.0 x 10^{-3} Ci/s and the emission rate for tritium was 3.5 x 10^{-4} Ci/s. One calculation was made for the December 15 monitoring period, which extended from 1015 to 1345 EST.

The input data for December 14 and 15 are presented in Table 5.6. These data are averages for the observation periods from the Space-Average-Mean (SAM) data that is routinely generated by the SRL Wind System. The plume rise calculations were based on the Briggs (1969) formula for a nonbuoyant jet. Two of the H-Area stacks are 2.4 m wide, with exit velocities of around 14 m/s. The third H-Area stack is 1.1 m wide, with an exit velocity of about 9.4 m/s. Plume rise estimates were based on the larger stack diameters and exit velocities. All stacks are 61 m tall. The P-Area stack is 5 m wide, with an exit velocity of around 3 m/s. A downwash correction for the P-Area stack on December 15 was neglected, because it was only 5 m. The mixed-layer depth estimates were based on observed temperature profiles from the 300 m WJBF-TV tower near the SRP, and mixed-layer model predictions. The data in Table 5.6 were the first and only estimates of the meteorological conditions during the monitoring periods, i.e., there was no model "tuning" of any sort.

The SRL Wind System components, including the transport and diffusion codes, are described by Garrett, Buckner, and Mueller (1983a) and by Garrett and Murphy (1981). The diffusion code used here is a Gaussian model modified to include removal by deposition. The diffusion rates are determined from equations by Pasquill and Briggs. Table 5.7 summarizes the calculations and includes the measured concentrations. The

Table 5.6 Meteorological input data for SRP calculations

Date	Wind Speed (m/s)	Wind Direction	σ_θ	σ_ϕ	Mixing Depth (m)	Stack Height (m)	Plume Rise (m)
12/14	1.8	30°	29	16	600	61	96
12/15	4.5	140°	14	10	500	61	35

calculations presented are for centerline maximum concentrations. Trajectory errors could not be assessed, because only one sampling station was used at each of the downwind distances where measurements were taken. Calculated trajectories showed that the stations must have been close to the center of the plumes most of the time. The measured values were taken from data provided by the EPA. The results are presented in graphical form in Figures 5.5, 5.6, and 5.7.

In Figure 5.5, the tritium concentrations measured on December 14 are compared to the WIND System prediction. The error bars were determined by the EPA. The averaging period was 2 to 3 hours, which, along with the steady winds and turbulence, produced data appropriate for comparison to Gaussian model predictions. The 25 percent underprediction at 1 km is most interesting, because Gaussian models usually overpredict. Recently developed diffusion models, which made use of convective boundary layer scaling theory, also predict higher concentrations close to the release point than the Gaussian model. Of course, there may be other factors responsible for the underprediction, such as the plume rise estimate, which was uncertain due to the different stack sizes in H-Area. To summarize, the results from December 14 are very good, particularly since there were only two sampling points.

Table 5.7 Summary of measured and calculated concentrations

Day	Station	Concentration (pCi/m^3) Obs	Concentration (pCi/m^3) Calc	Averaging Time (min)	Distance (km)	Isotope
12/14	3	19760±2800	15000	190	1.07	HT + HTO
12/14	4	5530± 810	5500	130	2.74	HT + HTO
12/15	6	260± 100	510	130	1.83	HTO
12/15	7	650± 100	510	135	2.29	HTO
12/15	6	1662± 502	1470	25	1.83	Ar-41
12/15	7	890± 570	1470	45	2.29	Ar-41
12/15	7	1304± 690	1470	60	2.29	Ar-41
12/15	9	295± 648	1000	20	4.42	Ar-41

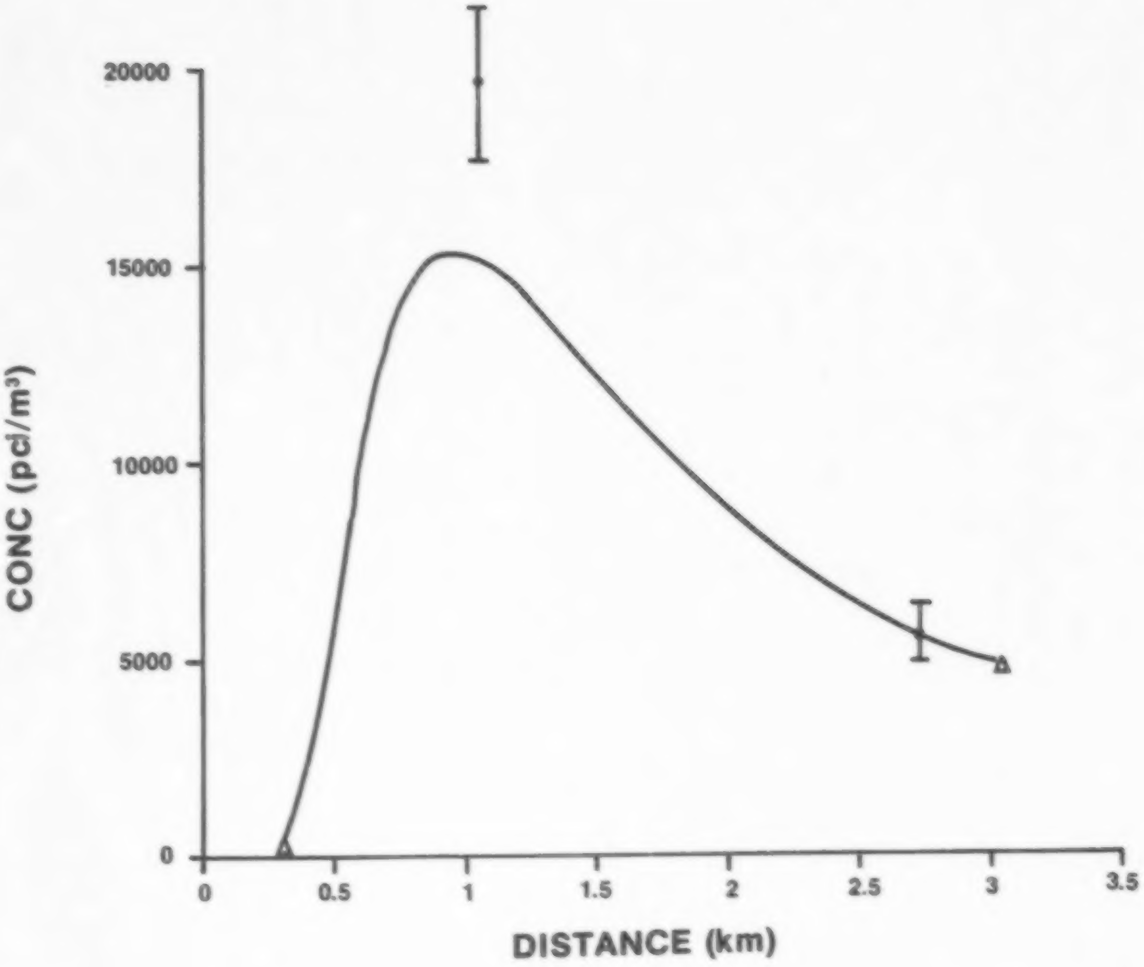

Fig. 5.5. A comparison of the December 14 EPA HTO measurements at H-Area with SRL calculated concentrations.

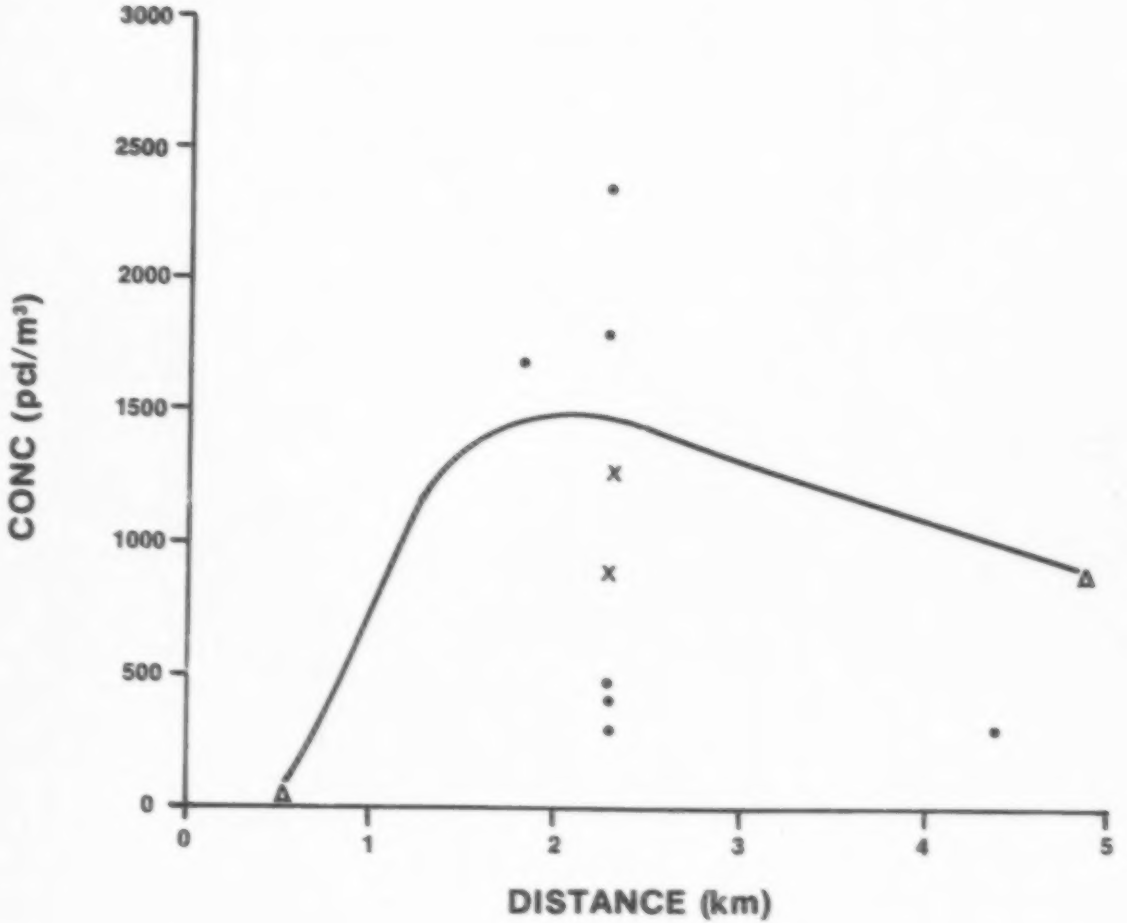

Fig. 5.6. A comparison of the December 15 EPA argon-41 measurements at P-reactor with SRL calculated concentrations.

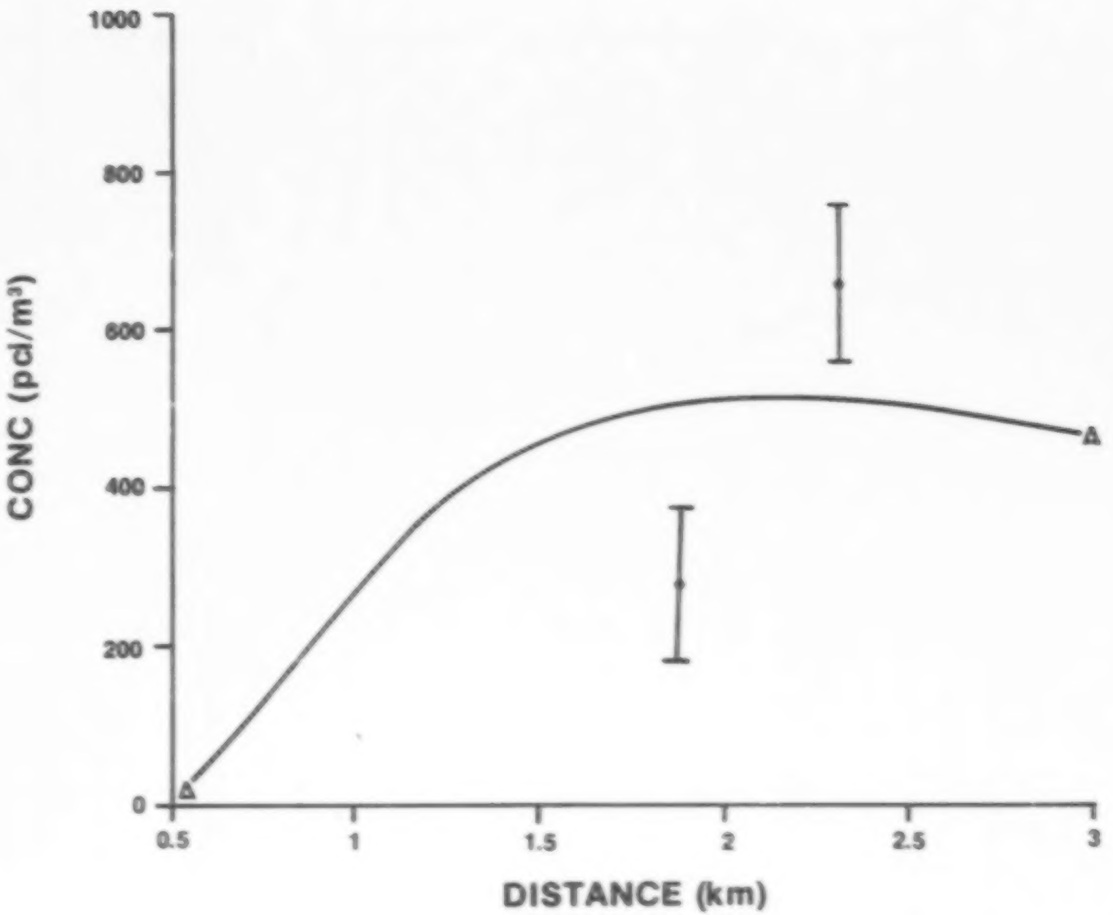

Fig. 5.7. A comparison of the December 15 EPA HTO measurements at P-reactor with SRL calculated concentrations.

Figure 5.6 presents results from the Ar-41 measurements on December 15. Twenty-minute samples are indicated by dots, and 40- to 60-minute averages of the 20-minute samples are indicated by X's. As expected, the longer averages are in better agreement with model predictions, and factor-of-2 agreement is achieved. Again, there is some underprediction close to the release point for the 20-minute averages.

Figure 5.7 presents results from the tritium measurements on December 15. Both data points represent two-hour averages. The underprediction at the 2.3 km station is so small (25 percent) that it can be attributed to any number of things, such as the plume rise prediction, errors in the wind speed and turbulence measurements, or fundamental limitations of the Gaussian model.

5.1.3 Discussion. Two calculational procedures were used to estimate plume concentrations and to determine their reliability by a comparison with measured concentrations. Both calculational methods estimated the concentrations of tritium in the plume from H-Area within a factor of 3 of the measured values. (Note--Agreement is generally considered good when computed and measured concentrations differ by a factor of 3 or less.) Attempts the following day to compute the tritium and argon-41 concentrations in the P-reactor plume demonstrated a misalignment of the P-Area meteorological tower. Tabulated wind directions obtained from the P-Area were corrected by empirically locating the P-Area plume during the measurement period. Using these corrected wind directions, measured-to-calculated ratios of χ/Q computed by the EPA method were usually within a factor of 3; however, some were as high as 8. The estimates of χ/Q made by DOE did agree closely with measured values; however, their procedure used average wind data for the complete collection period (1015 to 1340) from all area meteorological stations and assumed that the wind and plume directions were identical. The EPA method, using only data from the nearest meteorological station at P-area, had to be corrected for wind azimuth because of erroneously reported wind directions from that station. The wind direction instrumentation at the P-reactor station has subsequently been realigned (Ga83b).

6. SUMMARY AND CONCLUSIONS

6.1 General

A short-term one-visit field survey of airborne effluents was conducted at the Savannah River Plant (SRP) during December 13-16, 1982. The objectives of the survey were threefold: (1) to evaluate the reliability of the radioactive discharges reported by SRP; (2) to evaluate dispersion models by comparing measured radionuclide concentrations in the plume with computed values; and (3) to measure the concentrations of SRP related radionuclides in environmental samples collected at and around the Savannah River Plant.

In general, the major objectives of the field study were accomplished. Information was gained on environmental measurement techniques, the limitations and usefulness of the airborne dispersion models used to estimate environmental concentrations, and the extent of environmental contamination that has resulted from airborne releases by the SRP. These results are summarized briefly below.

An initial review of the surveillance program at the Savannah River Plant showed that tritium is the principal radionuclide present in off-site environmental samples due to plant releases. Radionuclides contributing to the population exposures to a smaller degree are Ar-41 and C-14. Particulate radionuclides appear to be effectively removed by emission controls. Dose estimates were confirmed by three independent models that gave similar dose equivalent rates for the principal radionuclides (see Table 1.3).

Nearly all samples collected during the study were split and analyzed separately by the EPA and SRP laboratories. Samples divided for comparative analyses included samples of stack effluents, vegetation, foods, and soil. Specific radionuclide analyses were performed, and the results are compiled for comparative purposes in Appendix D.

In general, the analytical results reported by the two laboratories are in good agreement. Values invariably fall within or near the reported analytical uncertainties. The expected, small differences in results were caused by the samples not being made homogeneous prior to splitting, by the difference in elapsed time that occurred between sample collection and analyses, and by small variations in laboratory procedures and practices.

6.2 Source Term Evaluation

The release rate (source term) measurements generally agreed with those reported by SRP (see Section 2.1.3 and Table 2.3). The tritium release rates compared very well, differing by 20 percent at H-Area and only by 2 percent at the P-reactor. The Ar-41 measurements were within 20 percent of the reported release rate, while other noble gas values agreed within a factor of two or better. Considering that different measurement techniques were employed by the two laboratories and that results from continuous samplers were compared with "grab" samples analyzed by EERF, the agreement is believed quite good. Thus, the release rates of radionuclides that are reported by SRP and ultimately used for modeling are considered reliable.

6.3 Plume Model Evaluation

The purpose of this evaluation was to determine how reliable plume dispersion models are for predicting environmental concentrations of radionuclides. For this purpose, tritium was measured at sites 3 and 4 in the plume formed by releases from the H-Area stacks, and at sites 6 and 7 confirmed by TRAC measurements to be in the plume from the P-reactor stacks. The rate at which H-3 was being discharged at the stacks was monitored simultaneously with the plume measurements. The release rate of Argon-41 was measured at the P-reactor stack and was included in the evaluation by also measuring its concentration in the plume at sites 6 and 7. On-site meteorological data were used in the model calculations.

The measured and predicted plume concentrations of H-3 agreed within a factor of 3 or better at sites 3 and 4. Most measurements at sites 6 and 7 were also well within a factor of 3 of computed values; however, some differed by as much as a factor of 8. Incorrectly reported wind directions from the P-area were corrected using field measurements to allow the computation of ground level χ/Q. The reported wind directions appeared to differ from the bearing of the actual plume by 18° to 36°.

Therefore, when using corrected meteorological data, computed and measured concentrations were in reasonable agreement. When erroneous meteorological data were used, large differences in measured and calculated values resulted. For example, under the meteorological conditions that existed during this study, a 10° error in the wind direction would result in a thirtyfold error. The study demonstrated that extreme care must be exercised to assure that the best and most appropriate meteorological data are being used in modeling short-term plume dispersion.

The ability to measure environmental concentrations of Ar-41, as well as Kr-85, was also demonstrated. The TRAC Laboratory measurements were well correlated with the Ar-41 and PIC measurements made in the plume. The Penn State high-pressure gas monitoring system proved to be a valuable asset to the study. Planning for future studies of this type, or of a related nature, should consider the usefulness of a high-pressure gas sampling system and include a concerted effort to coordinate closely field measurements with the best available meteorology.

6.4 Environmental Contamination

Environmental sampling was limited to a few grass, soil, and food samples. The on-site grass and soil samples contained quantities of tritium, uranium, and plutonium that were clearly in excess of background. An apparent excess of C-14 and Sr-90 in grass could not be definitely established without further sampling. The levels of contamination were largest in a location near H-Area known as the "farm". The contamination observed in these samples was known to exist as a result of earlier releases. In grass, uranium concentrations ranged up to 32 pCi/kg, plutonium to about 15 pCi/kg, and tritium exceeded 2200 pCi/kg fresh weight. Areas on which contamination has occurred are covered with dense vegetation, thereby eliminating the transport of contaminants by wind and water erosion to uncontrolled off-site areas.

Tritium was the only contaminant detected in off-site food products. Based on measured concentrations and the average annual intake of meat, milk, and leafy vegetables, an individual eating foods produced near the SRP site boundary would ingest about 440 nCi/yr of tritium. It was judged that of the C-14 measured in food products grown near the site, 1-2 dpm/gC could be due to Plant releases (see Table 4.4). Also, a plutonium concentration in vegetation was estimated by extrapolation to be about 0.1 fCi/g. These concentrations in food products could result in dose equivalent rates of 0.06 mrem/yr to the whole body due to H-3 and C-14, and possibly as much as 0.2 mrem/yr to the endosteal cells from plutonium. Thus, the food measurements that were made, although few in number, indicate that airborne releases from the Savannah River Plant do not significantly increase the radiation exposure to people living nearby.

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Introduction

The following tables identify results of analyses of particulate and charcoal filters obtained from chemical separations areas F and H, as well as reactors P, C, and K. These samples do not correspond to the time that environmental samples were being collected and, consequently, do not relate directly to the environmental study. They are included for purposes of general information and for comparison with the other data, as well as with results obtained by the Savannah River Laboratory for their portions of the same samples.

Table A.1 Radionuclide Airborne Effluent Emissions from Chemical Separations in F-Area

Radionuclide	Concentration (fCi/m^3)	Release Rate (pCi/s)
Co-60	7 ± 4	0.9 ± 0.5
Zr-95	1,028 ± 206	144 ± 29
Nb-95	1,238 ± 111	173 ± 16
Ru-103	234 ± 56	33 ± 8
Ru-106	678 ± 305	95 ± 43
Cs-137	180 ± 54	25 ± 8
Ce-141	28 ± 11	3.9 ± 1.5
Ce-144	514 ± 190	72 ± 27
Sr-89	< 584	< 82
Sr-90	778 ± 210	109 ± 30
U-234	108 ± 14	15 ± 2
U-235	6 ± 2	0.8 ± 0.3
U-238	812 ± 80	114 ± 11
Pu-238	11 ± 4	1.6 ± 0.5
Pu-239	29 ± 6	4.1 ± 0.9
Am-241	9 ± 2	1.2 ± 0.2
I-131	245 ± 73	34 ± 10

These results are based on analyses of daily filter samples combined for a period of one week. The fiberglass filters were cut in halves and split between EPA and SRP. Particulate filters included a total air volume of 856 m^3 over the period of December 5 to 12, 1982. The I-131 results were from a charcoal sample that included a total air volume of 2,181 m^3 over the period from December 7 to 14, 1982. Errors shown are ± 2σ.

Table A.2 Radionuclide Airborne Effluent Emissions from Chemical Separations in H-Area

Radionuclide	Concentration (fCi/m^3)	Release Rate (pCi/s)
Zr-95	1,308 ± 183	183 ± 26
Nb-95	748 ± 97	105 ± 14
Ru-103	981 ± 108	137 ± 15
Ru-106	9,486 ± 1,043	1,328 ± 146
Cs-137	70 ± 57	9.8 ± 8.0
Ce-144	1,355 ± 298	190 ± 42
Sr-89	< 1,170	< 160
Sr-90	< 234	< 33
U-234	17 ± 3	2.4 ± 0.4
U-235	0.5 ± 0.3	0.07 ± 0.05
U-238	3.0 ± 0.8	0.4 ± 0.1
Pu-238	254 ± 28	35 ± 4
Pu-239	7 ± 1	1.0 ± 0.2
Am-241	0.8 ± 0.5	0.11 ± 0.07
I-131	< 150	< 21

These results are based on analyses of daily filter samples combined for a period of one week. The fiberglass filters were cut in halves and split between EPA and SRP. Particulate filters included a total air volume of 428 m^3 over the period of December 5 to 12, 1982. The I-131 results were from a charcoal sample that included a total air volume of 856 m^3 over the period from December 7 to 14, 1982 Errors shown are ± 2σ.

Table A.3 Radionuclide Airborne Effluent Emissions from the P-Reactor

Radionuclide	Concentration (fCi/m^3)	Release Rate (pCi/s)
All γ	< 35	< 3
Sr-89	< 88	< 8
Sr-90	< 18	< 2
U-234	0.4 ± 0.2	0.04 ± 0.02
U-235	< 0.7	< 0.06
U-238	0.6 ± 0.3	0.05 ± 0.02
Pu-238	< 0.3	< 0.02
Pu-239	< 0.3	< 0.02
Am-241	< 0.3	< 0.02
I-131$^{(s)}$	76.5 ± 24.5	3.5 ± 1.1
I-131$^{(d)}$	< 50	< 2

All results excluding I-131 are from analyses of 72 mm diameter fiberglass filters, including one from the stack sampling system and one from the disassembly area exhaust sampling system. Particulate filters were split with SRP and EPA, each receiving approximately half. Charcoal filters included 155.7 g of charcoal in the stack sample and 148.5 g in the disassembly exhaust sample. The charcoal samples were analyzed separately for I-131 in both the stack (s) and the disassembly exhaust (d). Both the stack and disassembly exhaust sampling systems operated at 1 cfm flow rate for a total sample volume of 285 m^3 over the period from December 6 to 13, 1982. Stack flow rate during this period was 46 m^3/s and the disassembly exhaust flow rate was 42 m^3/s. Errors shown are ± 2σ.

Table A.4 Radionuclide Airborne Effluent Emissions from the C-Reactor

Radionuclide	Concentration (fCi/m^3)	Release Rate (pCi/s)
All γ	< 35	< 3
Sr-89	< 88	< 8
Sr-90	< 18	< 2
U-234	1 ± 0.4	0.08 ± 0.03
U-235	< 0.5	< 0.05
U-238	< 0.5	< 0.05
Pu-238	< 0.3	< 0.02
Pu-239	< 0.3	< 0.02
Am-241	< 0.3	< 0.02
I-131$^{(s)}$	< 35	< 2
I-131$^{(d)}$	289 ± 58	11 ± 2

All results excluding I-131 are from analyses of 72 mm diameter fiberglass filters, including one from the stack sampling system and one from the disassembly area exhaust sampling system. Particulate filters were split with SRP and EPA, each receiving approximately half. Charcoal filters included 111.6 g of charcoal in the stack sample and 162.7 g in the disassembly exhaust sample. The charcoal samples were analyzed separately for I-131 in both the stack (s) and the disassembly exhaust (d). Both the stack and disassembly exhaust sampling systems operated at 1 cfm flow rate for a total sample volume of 285 m^3 over the period from December 6 to 13, 1982. Stack flow rate during this period was 46 m^3/s and the disassembly exhaust flow rate was 38 m^3/s. Errors shown are $\pm 2\sigma$.

Table A.5 Radionuclide Airborne Effluent Emissions from the K-Reactor

Radionuclide	Concentration (fCi/m^3)	Release Rate (pCi/s)
All γ	< 35	< 3
Sr-89	< 88	< 7
Sr-90	< 18	< 2
U-234	0.8 ± 0.4	0.07 ± 0.03
U-235	< 0.5	< 0.05
U-238	0.6 ± 0.3	0.05 ± 0.03
Pu-238	0.5 ± 0.3	0.04 ± 0.02
Pu-239	< 0.3	< 0.02
Am-241	< 0.3	< 0.02
I-131$^{(s)}$	26 ± 21	1.2 ± 1.0
I-131$^{(d)}$	< 42	< 1.6

All results excluding I-131 are from analyses of 72 mm diameter fiberglass filters, including one from the stack sampling system and one from the disassembly area exhaust sampling system. Particulate filters were split with SRP and EPA, each receiving approximately half. Charcoal filters included 129.7 g of charcoal in the stack sample and 166.0 g in the disassembly exhaust sample. The charcoal samples were analyzed separately for I-131 in both the stack (s) and the disassembly exhaust (d). Both the stack and disassembly exhaust sampling systems operated at 1 cfm flow rate for a total sample volume of 285 m^3 over the period from December 6 to 13, 1982. Stack flow rate during this period was 46 m^3/s and the disassembly exhaust flow rate was 38 m^3/s. Errors shown are ± 2σ.

APPENDIX A

RELEASE RATE OF RADIONUCLIDES BASED ON WEEKLY COMPOSITED PARTICULATE AND CHARCOAL SAMPLES FROM THE CHEMICAL SEPARATIONS AND REACTOR FACILITIES

Samples Supplied by
D.J. Ratchford
Savannah River Plant

APPENDIX B

USE OF THE
PENN STATE NOBLE GAS MONITOR
TO ASSAY
Kr-85 AND Ar-41 IN AIR SAMPLES
COLLECTED DURING THE
EPA SURVEY OF THE
SAVANNAH RIVER PLANT

Data Supplied by
William P. Kirk
U.S. EPA, TMI Station

Introduction

As part of the SRP survey, compressed gas samples were collected in the plume from the operating P-reactor for a period of four hours on December 15, 1982, and analyzed for Ar-41 and Kr-85 using the Penn State Noble Gas Monitoring System. Additional Kr-85 analyses were done on the same samples by cryogenic separation and liquid scintillation counting at the Eastern Environmental Radiation Facility (EERF).

The Penn State Noble Gas Monitoring System was developed by Dr. William Jester, Department of Nuclear Engineering, Pennsylvania State University, several years ago for monitoring noble gases, particularly Ar-41, inside reactor containment buildings. Subsequently, the system has been used in the environment near several reactors and played a prominent part in the Kr-85 monitoring program during the June 28-July 11, 1980, purge of the containment building of the damaged Three Mile Island Unit II reactor (1,2,3,4,5,6). The system, described in detail in the foregoing references, utilizes a Windjammer Model 2310-00 5 CFM air compressor in the field to fill scuba bottles to 3,000 psig (Vol. 80 $ft.^3$, 2.3 m^3). The inlet hose to the air compressor contains a scrubbing train with particulate filtration and activated charcoal to remove radioiodine. The analytical part of the system consists of a roughly spherical 14.69 liter high-pressure stainless steel vessel with reentrant well in its base to permit insertion of a 10 percent efficient 50 cc Ge(Li) detector. The counting chamber is mounted in a welded steel angle iron frame and surrounded with 2 inches of lead (bricks) shielding. The detector is coupled to any appropriate spectroscopic high voltage supply, preamp, spectroscopic amplifier, multichannel analyzer, and output device such as printer and/or magnetic tape/disc unit.

The MCA is appropriately energy calibrated, and a scuba bottle with the compressed gas sample is cross-connected to the pressure chamber and the pressure allowed to equilibrate. The end pressure is of the order of 1200 psig. The sample is then counted for an appropriate period, usually 20-30 minutes, and the specific activity of Kr-85 and/ or Ar-41 calculated, using the net activity in the 0.514 MeV and 1.293 MeV peaks, respectively, and the volume (at STP) of gas in the counting chamber. Calibration and calculation procedures are given in the references (1,2,3,4,5,6).

The Penn State System was used in this survey because of the need for rapid, on-site analyses for Ar-41, whose 1.83 hr. half-life will not permit returning the sample to the laboratory for elaborate separation and analyses procedures. The Lower Limits of Detection (LLD) for Kr-85 and Ar-41 with this System are about 50,000 pCi/m^3 and 200 pCi/m^3, respectively. Since the cryogenic separation and liquid scintillation analysis method employed by EERF can detect 2-3 pCi/m^3 of Kr-85, the analysis for that isotope with the Penn State System was only done because it was concurrent with the Ar-41 determination.

Methods and Materials

The Penn State System was used as described in the basic references. The spectroscopic system used consisted of a TRACOR TN1710 Analyzer, a Canberra Model 3105 High Voltage Power Supply and a Canberra Model 2022 Spectroscopic Amplifier. Output was to a Texas Instrument "Silent 700" printing terminal.

The basic calibration for the system had been previously determined by Dr. Jester to be:

$$C = 6.6 \times 10^8 \left(\frac{AN}{P}\right) pCi/m^3 \text{ for Kr-85}$$

$$C = 3.95 \times 10^7 \left(\frac{AN}{P}\right) pCi/m^3 \text{ for Ar-41}$$

Where: C = Concentration in air of isotope in pCi/m^3.

AN = Net counts per second in the appropriate peak.

P = Pressure in the counting chamber (psig).

These factors account for the counting efficiency of the system as determined experimentally by evaporation of activation produced clathrates of known activity into the chamber and counting as well as by use of NBS sources.

The Kr-85 calibration was checked at Penn State on December 6-7, 1982 by recounting, with the original Penn State setup, an environmental air sample containing Kr-85 collected near Three Mile Island in July 1980. The results demonstrated that the system efficiency had not changed since the 1980 calibration and use. The EPA counting system was substituted for the Penn State equipment and the sample recounted with the same result within the statistics of the measurement.

The system was disassembled on December 8, 1982 and transported by GOV (2 1/2-ton truck) to the Savannah River Plant where it was reassembled on December 13, 1982 in Room 131, Building 735A (Environmental Laboratory Building). The instruments were connected to a regulated laboratory instrument circuit provided by SRP. The system was energy calibrated at about 0.5 KeV/channel for 4096 channels on December 14, 1982 using check sources containing Ba-133 (0.356 MeV), Cs-137 (0.662 MeV) and Co-60 (1.173, 1.332 MeV). The system parameters used are given in Table B.1. Eight, 20 channel wide "regions of interest" were established as listed in Table B.2. Regions were centered on the indicated energies.

Instrument background was determined for 40,000 seconds on the night of December 14-15 with a 1200 psig air sample collected outside the SRP environmental laboratory in the chamber and again for 50,000 seconds on the night of December 15-16 with P-10 counting gas at atmospheric pressure in the chamber. The energy calibration was checked on the mornings of December 15 and 16. The centroids of Regions 1, 3, 4, 5 and 6 were unchanged from the original calibrations.

The air compressor together with a rack containing 15 scuba bottles was mounted in a 2 1/2-ton government-owned truck on December 14 which was maneuvered as needed on December 15 to collect gas samples in the plume of the operating P-reactor. Plume location was predicted by SRP meteorologists and refined by the output of a large, directional NAI system in the SRP plume monitoring van which accompanied the EPA team. Scuba bottles were filled to 3,000 psig and immediately transported by truck (SRP personnel) to Building 735A for counting. The collection points and laboratory were 12-15 miles apart and samples were delivered to the laboratory from 30-60 minutes after the end of collection.

Table B.1 Instrument settings-Room A131, Building 735A, SRP

Bias Voltage	+ 2800 V
Coarse Gain	100
Fine Gain	.922
ULD	1.000
LLD	0.010
Zero	0.038

Polarity +

Bipolar Output:

4096 Channels - ~ 0.5 KeV/Channel

Table B.2 Spectral regions of interest setup in analyzer

Region	Energy (MeV)	Channels	Isotope
0	1.293	2580-2600	Ar-41
1	0.356	709-729	Ba-133
2	0.514	1019-1039	Kr-85(a)
3	0.662	1320-1340	Cs-137
4	1.173	2342-2362	Co-60
5	1.332	2660-2680	Co-60
6	1.462	2916-2936	K-40
7	1.593	3175-3192	--

(a) Annihilation peak.

A count time of 30 minutes was selected as a reasonable compromise between the need for a long count, to improve statistics, and rapid throughput to circumvent the 1.83 hour half-life of Ar-41. Retrospectively, a 20 minute count would have been better because the time required to bleed and purge the counting chamber after counting, to ensure that no crossover between samples occurred, resulted in a gradually increasing delay between collection and counting, thereby increasing the probability of obtaining a statistically insignificant result for samples that may have been significant if counted more promptly. Argon-41 results were corrected for decay during counting and for the period from the midpoint of collection to the start of counting.

Results and Discussion

The two background counts were statistically indistinguishable in all 8 regions. The mean value and composite standard deviation for each region was used in all subsequent calculations. The mean of the two overnight background count rates in the Ar-41 region was 0.0143 ± 0.0008 cps.

Eight gas samples were taken and analyzed on December 15. Sample No. 8 was an upwind background sample, while samples 1-7 were plume samples. The results of counting these samples are given in Table B.3. The only results that were statistically different from background were in the Ar-41 region for samples 1, 3, and 4, which were all more than 4.66σ above background, and the Kr-85 region for sample No. 8, which was significantly below the nocturnal background.

Because the purpose of the Ar-41 determinations was to validate a dispersion model and because the results obtained for the Ar-41 region were all above nocturnal background (see Figure B.1), Ar-41 concentrations were calculated and corrected for decay. Even though 4 of these samples were not significantly above background when counted, it is probable that counting immediately upon collection would have yielded a significant result. For purposes of model validation, it is felt that the constructed value at the midpoint of collection is more accurate than the "less than" value that would normally be reported. The "constructed" values are plotted in Figure B.2.

Table B.3 The gamma-ray analyses of the compressed gas samples for Ar-41

Sample No.	Collection Site	Collection Period		Count Time[(a)] On	Equil. Pressure, psig	Total Counts
		Start	Stop			
001	6	1015	1040	1111	1210	89
002	7	1048	1107	1213	1215	34
003	7	1113	1133	1317	1210	83
004	7	1142	1200	1358	1200	66
005	7	1203	1227	1448	1200	34
006	7	1230	1248	1530	1200	33
007	9	1321	1340	1612	1190	31
008	8	1404	1424	1657	1190	27

Table B.3 The gamma-ray analyses of the compressed gas samples for Ar-41 (Continued).

Sample No.	Gross counts, cps	Net counts,[(b)] cps	Ar-41,[(c)] pCi/m^3	Decay Time, hr	Corrected Ar-41 Conc.[(d)] pCi/m^3
001	0.0494 ± 0.0052	0.035 ± 0.005	1258 ± 379	0.73	1662 ± 502
002	0.0189 ± 0.0033	0.0046 ± 0.0033	165 ± 235	1.27	266 ± 382
003	0.0461 ± 0.0051	0.0318 ± 0.0051	1140 ± 366	1.90	2343 ± 752
004	0.0367 ± 0.0045	0.0224 ± 0.0046	809 ± 333	2.12	1806 ± 743
005	0.0189 ± 0.0032	0.0046 ± 0.0033	166 ± 238	2.55	436 ± 627
006	0.0183 ± 0.0032	0.0040 ± 0.0033	145 ± 237	2.85	427 ± 702
007	0.0172 ± 0.0031	0.0029 ± 0.0032	106 ± 232	2.70	295 ± 648
008	0.0150 ± 0.0029	0.0007 ± 0.0030	<220	2.71	<640

(a) Samples collected and counted on 12/15/82.
(b) The mean background of 0.0143 + 0.0008 cps has been subtracted.
(c) Corrected for decay during 30 minute counting period.
(d) Concentration corrected to the midpoint of collection.

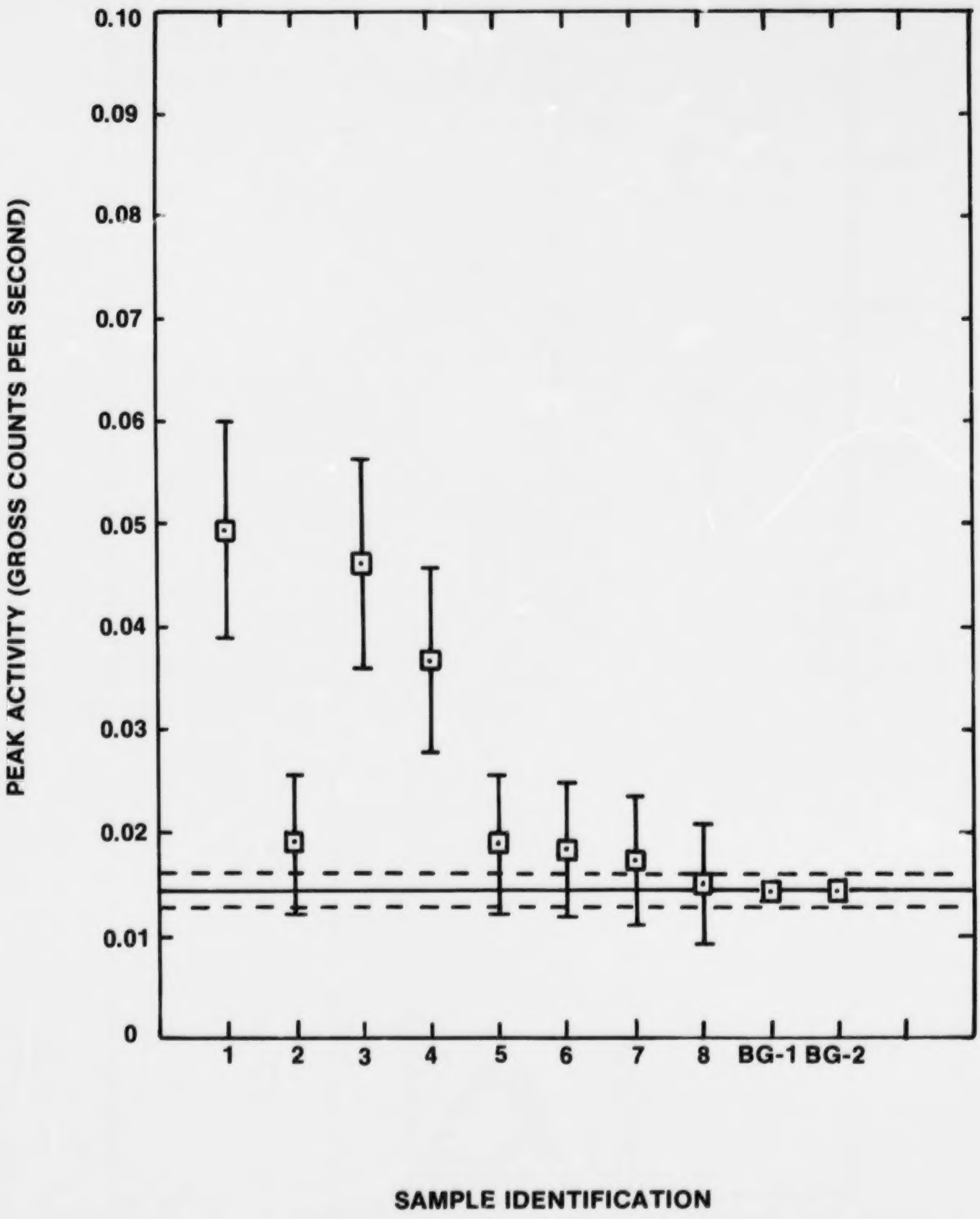

Fig. B.1. The gross count rate of argon-41 with 2-σ error bars. Also shown is the mean nocturnal background (—) with its 2-σ uncertainty (---)

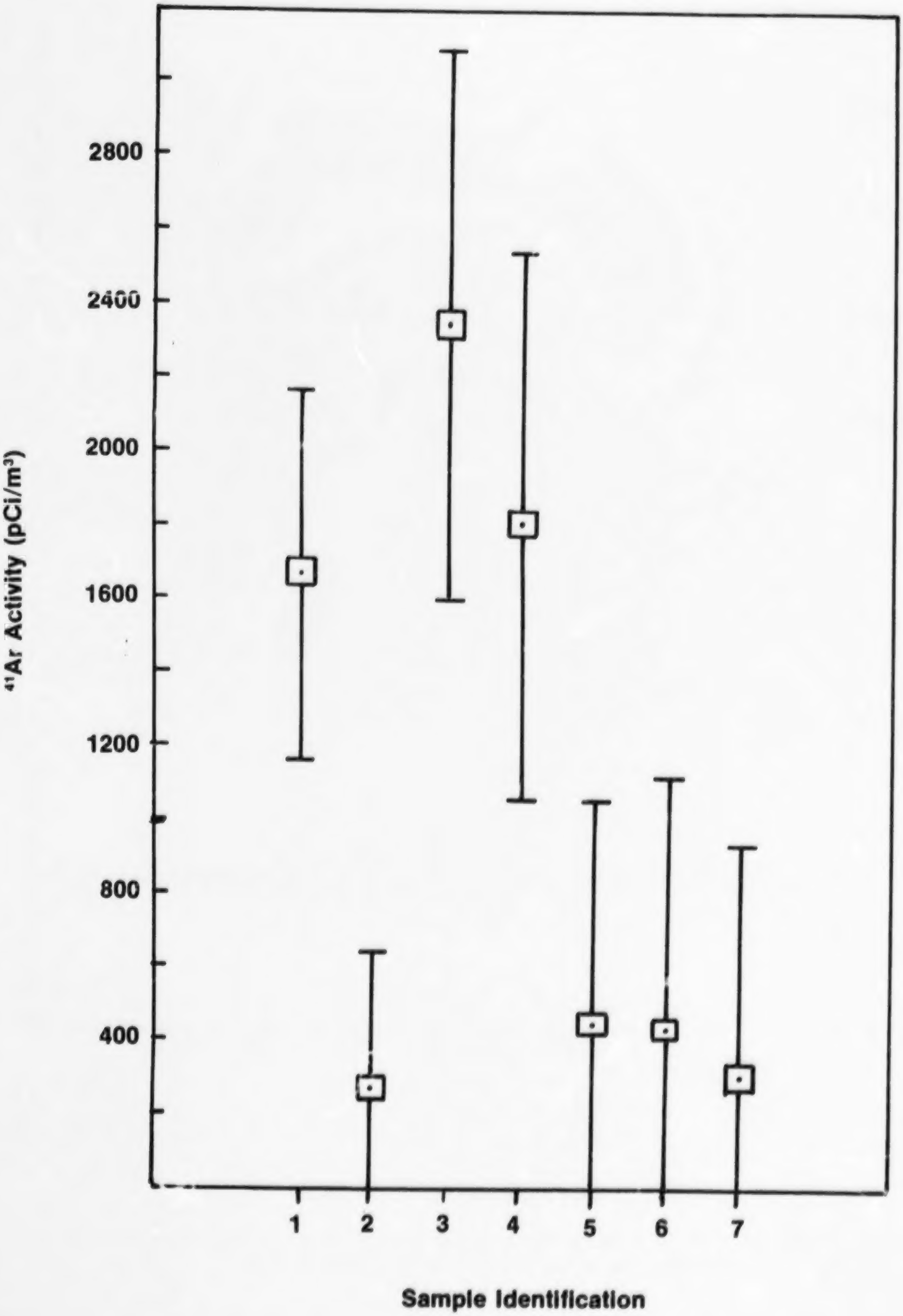

Fig. B.2. The net concentration of argon-41 corrected for decay to the midpoint of collection.

The low values obtained in the Kr-85 region for sample No. 8, a background, led to a careful examination of the data from this region for all samples. When compared to the combined nocturnal background data, six of the eight samples were below the background, No. 8 significantly so, and there appeared to be more variations than usual. Because of these findings, malfunction of the MCA (or amplifier/preamp, power supply chain) was suspected and data for each region of interest was plotted against its own nocturnal background. The only two regions with variability beyond statistical expectations were those for Ar-41 and Kr-85, which, together with the constancy of the energy calibration, refutes the idea of system malfunction. It appears, therefore, probable that there is some source of photons in the 0.51-0.52 MeV range present at night at the location of the counter, and the background in the Kr-85 spectral peak is considerably lower than experimentally determined.

The observed random variability in the Kr-85 region is believed due to contamination of the scuba tanks by residual Kr-85 from their earlier use at TMI.

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System Description

A plume monitor aboard the Tracking Radiological Atmospheric Contaminants (TRAC) System gives the mobile laboratory an ability to detect, locate and estimate concentrations of atmospheric radionuclides emitting penetrating radiations. An array of twelve sodium iodide detectors is the central component of the monitor, and is approximately the same size used in aerial surveying and prospecting. Shadowing from other equipment aboard the laboratory and interferences from natural activities in the earth have been minimized by placing the array in a roof level compartment and by shielding it along the bottom and sides. The array is divided into four groups of three detectors by a cruciform shield; count rate comparisons between these groups yields information related to plume locations. Each detector has a 4 x 4 inch face, and each quadrant contains a 4 inch, 8 inch and 12 inch long detector laying on its side. The detector shield assembly and the data-acquisition electronics assembly inside the laboratory are shock mounted for the mobile application.

The TRAC System counting data listed in the following table were collected simultaneously with the Ar-41 compressed air samples. Each value listed is a 60 second count ending on the time indicated in the second column. The first sector is directional toward the left front, the second sector toward the right front, the third toward the left rear and the fourth sector is directional toward the right rear. The sum of the counts obtained in the four sectors is given in the last column of the table.

Table C.1 Plume Measurements

Sample Period	Time, Hours (AM)	Total Counts In Each Sector(a)				Total Counts
		I	II	III	IV	
II	10.87	586	511	528	593	2218
	10.92	134	340	621	483	1578
	10.95	494	468	599	732	2293
	10.97	357	338	878	639	2212
	11.00	457	265	906	596	2224
	11.03	239	369	779	963	2350
	11.07	518	537	746	780	2581
	11.08	94	268	623	347	1332
	11.12	0	71	211	151	433
(b)	11.13	209	490	596	601	1896
	11.17	1627	1595	1773	1550	6545
	11.20	1759	1721	2010	1687	7177
III	11.22	3749	3395	3921	3767	14832
	11.24	3618	3569	3716	3730	14633
	11.27	2485	2520	3023	2696	10726
	11.29	3368	3506	3346	3441	13661
	11.32	2461	2354	2686	2492	9993
	11.34	2328	2418	2423	2474	9643
	11.37	2454	2783	3219	2726	11182
	11.40	3414	3318	3055	3401	13188
	11.43	3427	3855	3638	3534	14454
	11.45	2820	2948	3293	3282	12343
	11.48	2829	2888	3421	3475	12613
	11.50	2094	2014	2756	2708	9572
	11.52	1932	2201	2885	2580	9598
	11.55	1975	2047	2599	2336	8957
(b)	11.57	1705	1377	2178	1888	7148
	11.60	561	435	717	628	2341
	11.62	617	713	1135	936	3441
	11.66	1782	1674	1912	2478	7846
IV	11.68	2466	2273	2715	2800	10254
	11.71	3664	3576	3630	3907	14777
	11.73	2932	3017	3484	3217	12650
	11.75	3151	2953	3445	3421	12970
	11.78	2884	2408	3235	2935	11462
	11.81	2675	2724	3133	2988	11520
	11.83	2337	2556	2636	2795	10324
	11.86	2135	2135	2181	1909	8360
	11.88	1440	1697	1697	1643	6477
	11.91	2182	2418	2265	2152	9017
	11.93	1471	1704	1367	1469	6011
	11.96	2477	2615	2335	2054	9481
	11.99	2131	2503	2373	2422	9429

Table C.1 Continued

Sample Period	Time, Hours (PM)	Total Counts In Each Sector[(a)]				Total Counts
		I	II	III	IV	
(b)	12.01	2122	2033	1829	1895	7879
	12.03	1676	2004	1448	1696	6824
	12.06	1342	1658	1138	1066	5206
	12.08	1823	2238	1713	2145	7919
	12.11	2907	3496	2883	2829	12115
	12.13	1942	2106	2001	1889	7938
	12.16	849	1070	372	728	3019
	12.18	1644	1733	1477	1613	6467
V	12.21	1493	1288	1498	1433	5712
	12.25	535	622	343	396	1896
	12.27	588	665	598	495	2346
	12.29	664	629	740	736	2769
	12.32	1123	1053	1219	1099	4494
	12.34	2805	2882	1627	1614	8928
	12.37	2781	2571	1901	1771	9024
	12.39	2256	2252	2214	2073	8795
	12.43	2389	2479	2482	2586	9936
(b)	12.46	1402	1716	1721	1691	6530
	12.48	1297	1531	1191	1541	5560
	12.51	769	909	568	610	2856
	12.54	448	516	112	413	1489
	12.56	432	415	237	271	1355
	12.58	157	284	48	263	752
	12.62	892	1138	730	881	3641
VI	12.64	2112	2421	2052	1989	8574
	12.67	1249	1829	1006	771	4855
	12.69	860	1019	573	854	3306
	12.72	2170	2208	1938	2337	8653
	12.74	1040	992	940	1266	4238
	12.77	615	582	507	473	2177
	12.81	784	895	831	893	3403
	12.83	554	628	516	524	2222
(b)	12.86	246	205	130	282	863
	12.88	0	55	0	183	238
	1.35	594	563	698	638	2493
	1.39	142	328	217	311	998
	1.42	175	307	341	317	1140
	1.53	370	462	440	474	1746
VII	1.56	172	509	357	258	1296
	1.60	567	623	450	500	2140
	1.62	599	543	595	356	2093
	1.65	390	565	355	517	1827
	1.68	565	744	659	692	2660

Table C.1 Continued

Sample Period	Time, Hours (PM)	Total Counts In Each Sector[a] I	II	III	IV	Total Counts
(b)	1.72	759	948	896	933	3536
	1.74	728	548	556	697	2529
	1.77	834	860	905	639	3238
	1.79	547	626	609	573	2355
	1.82	524	542	670	773	2509
VIII	2.08	68	35	0	0	103
	2.11	0	11	45	0	56
	2.13	0	17	15	0	32
	2.17	0	71	20	0	91
	2.20	9	0	25	13	47
	2.28	0	0	16	16	32

(a) Counts measured in 60 seconds on December 15, 1982.
(b) Counts obtained between gas sampling periods.

APPENDIX C

THE TRAC LABORATORY
PLUME MONITOR

Data Supplied by
R.A. Sigg
Environmental Sciences Division
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Savannah River Plant

APPENDIX D

A COMPARISON OF THE INTERLABORATORY ANALYSES

Stack Effluent Sample Analyses

Stack effluent samples were collected from P-reactor and from the F- and H-chemical separations facilities. Samples collected were particulates, gases, condensed water vapor, and a charcoal filter sample for radioiodine. The sampling procedures are described in Sections 2.2.2 and 2.3.2 of this report. Samples of each type were divided by SRP staff for analyses by the two laboratories. Filters were split only approximately into equal parts. Gas samples were collected consecutively from the same port. The condensed water vapor samples were taken from the same reservoir. Thus, only for the water sample was homogeneity of sample assured.

The results reported by both laboratories are listed in Tables D.1, D.2 and D.3 for comparison. The results of the EPA laboratory were taken directly from Tables 2.2, 2.5 and 2.6 of Section 2, respectively. All results of the P-reactor effluent samples are in good agreement. The gross beta-gamma values reported by the SRP for the particulates agree with the specific radionuclide analyses listed for the EPA laboratory. Good agreement also exists between the results reported for effluent samples from the F- and H- facilities. Small differences in concentrations of the alpha emitters may be due to an uneven distribution of alpha-emitting particles on the filters. Differences in the reported I-131 concentrations may also be the result of uneven distribution on the charcoal filter. The SRP analyzed the whole charcoal filter before splitting, while the EPA analyzed only a part of the filter at a later date.

In addition to the split samples discussed above, daily particulate filter samples were combined for a period of one week, cut approximately in halves, and split between the EPA and SRP laboratories (see Appendix A for a detailed description of these samples). The analytical results reported by the two laboratories for the analyses of these samples are listed in Tables D.4 through D.8. A comparison of these data show reasonable agreement between the results for the analyses of stack samples from the three reactors (Tables D.4, D.5, and D.6). The results for samples from the Chemical Separations Areas (Tables D.7 and D.8) show general agreement except for some plutonium results and the EPA's values for I-131 are consistently lower than those reported by SRP.

Environmental and Food Sample Analyses

Samples of foods, vegetation, and soil were collected during this study on or near the Savannah River Plant site and split for separate analyses by the two laboratories. Detailed information on the collection of these samples is given in Section 4 of this report. The environmental sample splits were collected separately within a few meters of one another. The food samples were collected by the SRP; the beef sample was butchered from the same cow, the milk was obtained from a dairy, and the collards were from two farms. Neither the food samples nor the environmental samples were homogenized before splitting. The analytical results reported by the laboratories for these analyses are listed for comparison in Tables D.9, D.10, and D.11.

A review of the data in the tables show generally good agreement between concentrations reported by the two laboratories. Differences in the reported values for vegetation and food samples generally fall within the two standard deviation error. The only exception is the reported concentration of plutonium in the vegetation sample from Site 11. The values reported by the EPA laboratory are significantly lower than those given by the SRP. Site 11 was located near the Plant west boundary and there would likely be less plutonium associated with soil and flora within this area.

The EPA reported tritium concentrations in these samples on the basis of fresh weight of sample in order to more easily compute the effective dose to people eating the foods (see Table 4.2). However, the basic data for tritium measured in the water fraction of these samples were available enabling a direct comparison of the tritium concentrations measured by the two laboratories. These concentrations are listed for comparison in Table D.9. For most of the samples agreement was very good. Small differences are observed only in the results for samples containing small quantities of tritium.

Summary

Agreement between laboratory analyses were generally good. The largest observed differences were the values reported for plutonium and I-131 in the week-long samples from F- and H-Area stacks. Small differences in the results were expected considering the various time delays between sample collection and analyses, differences in analytical procedures and practices, and particularly the inhomogeneity of the split samples.

Table D.1 Stack Effluent Samples from P-Reactor.

Type Sample	Radionuclide	EPA Measured Concentration (μCi/m^3)	SRP Measured Concentration (μCi/m^3)
Particulates	Gamma emitting	< 8E-8	Gross Beta-Gamma < 2E-7
Particulates	Sr-89	< 4E-8	
Particulates	Sr-90	< 8E-9	
Particulates	U-234	< 3E-9	
Particulates	U-235	< 3E-9	Total Alpha < 1E-8
Particulates	U-238	(1.1 ± 0.3)E-8	
Particulates	Pu-238	< 1E-9	
Particulates	Pu-239	< 1E-9	
Particulates	Am-241	< 1E-9	
Charcoal	I-131	< 3E-7	< 1E-11
Water	H-3	(8.4 ± 0.3)E+0	(9.0 ± 0.4)E+0
Stack gas	C-14	(7 ± 2)E-3	NM
Stack gas	Ar-41	(2.8 ± 0.2)E+1	(2.3 ± 0.3)E+1
Stack gas	Kr-85	(1.2 ± 0.2)E-5	< 5E-2
Stack gas	Kr-85m	(2 ± 1)E-1	(3 ± 0.5)E-1
Stack gas	Kr-87	(1.4 ± 0.9)E-1	(1.3 ± 0.2)E-1
Stack gas	Kr-88	(5 ± 2)E-1	(2 ± 0.3)E-1
Stack gas	Xe-133	NM	(3 ± 0.5)E-1
Stack gas	Xe-135	(8 ± 1)E-1	(6 ± 1)E-1

Notes: 1. Samples were collected during the following periods; particulates from 0830 on 12/13 to 0830 on 12/16, water from 0830 on 12/15 to 0830 on 12/16, and stack gas at 1400 on 12/15.

NM - Not Measured

Table D.2 Chemical Separations F-Area Stack Effluent Samples

Radionuclide	EPA Measured Concentration (pCi/m^3)	SRP Measured Concentration (pCi/m^3)
Zr-95	1.04 ± 0.06	1.5 ± 0.14
Nb-95	1.24 ± 0.04	1.4 ± 0.14
Ru-106	1.5 ± 0.2	2.3 + 0.86
I-131	0.02 ± 0.01	< 0.10
Cs-137	0.06 ± 0.02	< 0.13
Ru-103	0.52 ± 0.04	0.71 ± 0.07
Ce-141	0.03 ± 0.02	< 0.12
Ce-144	0.58 ± 0.08	0.38 ± 0.15
Sr-89	< 2.0	0.24 ± 0.08
Sr-90	< 0.4	
U-234	0.11 ± 0.03	0.6 ± 0.01
U-235	< 0.033	
U-238	1.2 ± 0.2	
Pu-238	0.01 ± 0.01	0.028 ± 0.004
Pu-239	0.02 ± 0.01	0.042 ± 0.004
Am-241	< 0.001	0.07 ± 0.01
I-131*	0.07 ± 0.01	0.8 ± 0.02

Notes:
1. Particulate samples were split between SRP and EPA, and results shown are estimates based on assumption of equal portions.
2. Particulates were collected during the period 0900 on 12/14 to 0900 on 12/15 and iodine was collected during the period 0900 on 12/7 to 0900 on 12/14.

* Charcoal filter sample. All other samples are particulate filters. SRP analysis based on whole sample before splitting with EPA and the values were decay corrected to the middle of the sampling period.

Table D.3 Chemical Separations H-Area Stack Effluent Samples

Radionuclide	EPA Measured Concentration (pCi/m^3)	SRP Measured Concentration (pCi/m^3)
Zr-95	1.6 ± 0.2	1.7 ± 0.3
Nb-95	0.98 ± 0.09	0.7 ± 0.3
Ru-103	2.9 ± 0.2	3.1 ± 0.2
Ru-106	31 ± 1	31 ± 1.8
Cs-134	0.082 ± 0.005	< 0.18
Cs-137	0.23 ± 0.05	< 0.26
Ce-144	2.3 ± 0.7	2.9 ± 0.04
Sr-89	< 8.0	0.82 ± 0.12
Sr-90	< 1.6	
U-234	0.04 ± 0.01	0.02 ± 0.001
U-235	< 0.0065	
U-238	0.017 ± 0.006	
Pu-238	0.22 ± 0.03	0.13 ± 0.07
Pu-239	0.003 ± 0.002	0.01 ± 0.01
Am-241	< 0.0025	0.02 ± 0.01
I-131*	< 0.15	0.74 ± 0.60

Notes: 1. Particulates were collected during the period 0900 on 12/14 to 0900 on 12/15 and iodine was collected during the period 0900 on 12/7 to 0900 on 12/14.

2. Particulate filter samples were split between SRP and EPA, and resuls shown are estimates based on assumption of equal portions.

* Charcoal filter sample. All other samples are particulate filters. SRP analysis based on whole sample before splitting with EPA and the values were decay corrected to the middle of the sampling period.

Table D.4 Radionuclide Airborne Effluent Emissions from the P-Reactor

Radionuclide	EPA Concentration (fCi/m^3)	SRP Concentration (fCi/m^3)
All γ	< 35	Gross Beta-Gamma < 33
Sr-89	< 88	
Sr-90	< 13	
U-234	0.4 ± 0.2	
U-235	< 0.7	Gross Alpha < 1.3
U-238	0.6 ± 0.3	
Pu-238	< 0.3	
Pu-239	< 0.3	
Am-241	< 0.3	
I-131$^{(s)}$*	76.5 ± 24.5	170 ± 80
I-131$^{(d)}$*	< 50	< 33

All results excluding I-131 are from analyses of 72 mm diameter fiberglass filters, including one from the stack sampling system and one from the disassembly area exhaust sampling system. Particulate filters were split with SRP and EPA each receiving approximately half. Charcoal filters included 155.7 g of charcoal in the stack sample and 148.5 g in the disassembly exhaust sample. The charcoal samples were analyzed separately for I-131 in both the stack$^{(s)}$ and the disassembly exhaust$^{(d)}$. Both the stack and disassembly exhaust sampling systems operated at 1 cfm flow rate for a total sample volume of 285 m^3 over the period from December 6 to 13, 1982. Stack flow rate during this period was 45 m^3/s and the disassembly exhaust flow rate was 42 m^3/s. Errors shown are ± 2σ.

* I-131 results were decay corrected to the middle of the sampling period.

Table D.5 Radionuclide Airborne Effluent Emissions from the C-Reactor

Radionuclide	EPA Concentration (fCi/m^3)	SRP Concentration (fCi/m^3)
All γ	< 35	Gross Beta-Gamma < 13
Sr-89	< 88	
Sr-90	< 18	
U-234	1 ± 0.4	
U-235	< 0.5	Gross Alpha < 1.2
U-238	< 0.5	
Pu-238	< 0.3	
Pu-239	< 0.3	
Am-241	< 0.3	
I-131$^{(s)*}$	< 35	
I-131$^{(d)*}$	289 ± 58	590 ± 470

All results excluding I-131 are from analyses of 72 mm diameter fiberglass filters, including one from the stack sampling system and one from the disassembly area exhaust sampling system. Particulate filters were split with SRP and EPA each receiving approximately half. Charcoal filters included 111.6 g of charcoal in the stack sample and 162 g in the disassembly exhaust sample. The charcoal samples were analyzed separately for I-131 in both the stack$^{(s)}$ and the disassembly exhaust$^{(d)}$. Both the stack and disassembly exhaust sampling systems operated at 1 cfm flow rate for a total sample volume of 285 m^3 over the period from December 6 to 13, 1982. Stack flow rate during this period was 46 m^3/s and the disassembly exhaust flow rate was 38 m^3/s. Errors shown are ± 2σ.

* I-131 results were decay corrected to the middle of the sampling period.

Table D.6 Radionuclide Airborne Effluent Emissions from the K-Reactor

Radionuclide	EPA Concentration (fCi/m^3)	SRP Concentration (fCi/m^3)
All γ	< 35	Gross Beta-Gamma < 38
Sr-89	< 88	
Sr-90	< 18	
U-234	0.8 ± 0.4	
U-235	< 0.5	Gross Alpha < 1.8
U-238	0.6 ± 0.3	
Pu-238	0.5 ± 0.3	
Pu-239	< 0.3	
Am-241	< 0.3	
I-131$^{(s)*}$	26 ± 21	< 42
I-131$^{(d)*}$	< 42	< 33

All results excluding I-131 are from analyses of 72 mm diameter fiberglass filters, including one from the stack sampling system and one from the disassembly area exhaust sampling system. Particulate filters were split with SRP and EPA each receiving approximately half. Charcoal filters included 129.7 g of charcoal in the stack sample and 166.0 g in the disassembly exhaust sample. The charcoal samples were analyzed separately for I-131 in both the stack$^{(s)}$ and the disassembly exhaust$^{(d)}$. Both the stack and disassembly exhaust sampling systems operated at 1 cfm flow rate for a total sample volume of 285 m^3 over the period from December 6 to 13, 1982. Stack flow rate during this period was 46 m^3/s and the disassembly exhaust flow rate was 38 m^3/s. Errors shown are ± 2 σ.

* I-131 results were decay corrected to the middle of the sampling period.

Table D.7 Radionuclide Airborne Effluent Emissions from Chemical Separations in F-Area

Radionuclide	EPA Concentration (fCi/m^3)	SRP Concentration (fCi/m^3)
Co-60	7 ± 4	< 14
Zr-95	1,028 ± 206	873 ± 40
Nb-95	1,238 ± 111	1,040 ± 20
Ru-103	234 ± 56	200 ± 20
Ru-106	678 ± 305	520 ± 190
Cs-137	180 ± 54	157 ± 10
Ce-141	28 ± 11	53 ± 30
Ce-144	514 ± 190	380 + 60
Sr-89	< 584	670 ± 120
Sr-90	778 ± 210	
U-234	108 ± 14	870 ± 108
U-235	6 ± 2	
U-238	812 ± 80	
Pu-238	11 ± 4	152 ± 20
Pu-239	29 ± 6	220 ± 28
Am-241	9 ± 2	35 ± 24
I-131*	245 ± 73	1,760 ± 820

These results are based on analyses of daily filter samples combined for a period of one week. The fiberglass filters were cut in halves and split between EPA and SRP. Particulate filters included a total air volume of 856 m^3 over the period of December 5 to 12, 1982. The I-131 results were from a charcoal sample that included a total air volume of 2,181 m^3 over the period from December 7 to 14, 1982. Errors shown are $\pm 2\sigma$.

* I-131 results were decay corrected to the middle of the sampling period.

Table D.8 Radionuclide Airborne Effluent Emissions from Chemical Separations in H-Area

Radionuclide	EPA Concentration (fCi/m^3)	SRP Concentration (fCi/m^3)
Zr-95	1,308 ± 183	810 ± 60
Nb-95	748 ± 97	450 ± 40
Ru-103	981 ± 108	690 ± 50
Ru-106	9,486 ± 1,043	6,500 ± 270
Cs-137	70 ± 57	70 ± 20
Ce-144	1,355 ± 298	880 ± 130
Sr-89	< 1,170	< 520
Sr-90	< 234	
U-234	17 ± 3	70 ± 24
U-235	0.5 ± 0.3	
U-238	3.0 ± 0.8	
Pu-238	254 ± 28	122 ± 41
Pu-239	7 ± 1	70 ± 24
Am-241	0.8 ± 0.5	< 17
I-131*	< 150	1,220 ± 620

These results are based on analyses of daily filter samples combined for a period of one week. The fiberglass filters were cut in halves and split between EPA and SRP. Particulate filters included a total air volume of 856 m^3 over the period of December 5 to 12, 1982. The I-131 results were from a charcoal sample that included a total air volume of 2,181 m^3 over the period from December 7 to 14, 1982. Errors shown are $\pm 2\sigma$.

* I-131 results were decay corrected to the middle of the sampling period.

Table D.9 The Tritium Concentration in the Water of Vegetation and Food Samples, pC/ml

Site	Sample Type	EPA Measured Concentration	SRP Measured Concentration
		On-Site Samples	
4	Grass	153 ± 1	120 ± 1
10A	Grass	3,919 ± 6	3,600 ± 2
10B	Grass	85 ± 1	75 ± 1
11	Grass	11.4 ± 0.4	4.9 ± 0.4
		Off-Site Samples	
12	Collards	0.6 ± 0.2	0.7 ± 0.4
13	Collards	11.0 ± 0.4	12.0 ± 0.5
15	Beef	1.0 ± 0.2	0.02 ± 0.33
14	Milk	1.2 ± 0.2	0.6 ± 0.4

Table D.10 Radionuclide concentrations measured in vegetation and soil samples on site

Site	Date	Analyses	EPA Radionuclide Concentration		SRP Radionuclide Concentration	
			Vegetation pCi/kg fresh	Soil pCi/kg dry	Vegetation pCi/kg fresh[c]	Soil pCi/kg dry
4	12/14/82	Be-7	4,100 ± 500	0.14 ± 0.11	5,900 ± 13,700	< 0.13
		K-40	1,900 ± 700	0.98 ± 0.18	10 ± 15,000	0.6 ± 1.2
		Co-60	50 ± 40	< 0.05	5,200 ± 16,300	0.14 ± 0.38
		Cs-137	810 ± 80	1.76 ± 0.05	700 ± 130	1.1 ± 0.13
		C-14[a]	19.6 ± 1.5	NM	NM	NM
		Sr-90	870 ± 50	< 0.23	1,000 ± 830	NM
		Pu-238	3.2 ± 1.0	< 0.03	4.2 ± 1.4	NM
		Pu-239	4.1 ± 1.2	0.04 ± 0.02	6.3 ± 1.7	NM
		U-234	17 ± 3	0.67 ± 0.10	NM	NM
		U-238	17 ± 3	0.70 ± 0.10	NM	NM
10A	12/16/82	Be-7	2,300 ± 300	< 0.2	2,100 ± 13,600	< 0.13
		K-40	1,500 ± 600	3.6 ± 0.2	10 ± 15,200	3.7 ± 1.0
		Cs-137	420 ± 60	0.54 ± 0.03	1,100 ± 1,400	0.61 ± 0.09
		Ru-106	< 60	0.11 ± 0.06	10 ± 12,000	
		C-14[a]	18.0 ± 1.4	NM	NM	NM
		Sr-90	210 ± 30	< 0.10	680 ± 820	NM
		Pu-238	4.3 ± 1.0	0.67 ± 0.14	12 ± 2.2	NM
		Pu-239	7.5 ± 1.5	2.2 ± 0.4	8.5 ± 1.9	NM
		U-234	7.7 ± 1.4	0.89 ± 0.15	NM	NM
		U-238	5.6 ± 1.1	0.89 ± 0.15	NM	NM

Table D.10 (Continued)

Site	Date	Analyses	EPA Radionuclide Concentration Vegetation pCi/kg fresh	EPA Radionuclide Concentration Soil pCi/kg dry	SRP Radionuclide Concentration Vegetation pCi/kg fresh[(c)]	SRP Radionuclide Concentration Soil pCi/kg dry
10B	12/16/82	Be-7	2,700 ± 400	< 0.2	8,700 ± 14,000	< 0.13
		K-40	1,700 ± 500	1.08 ± 0.16	4,400 ± 15,600	1.2 ± 1.1
		Cs-137	460 ± 60	0.49 ± 0.03	1,000 ± 1,400	0.65 ± 0.1
		C-14(a)	20.1 ± 1.6	NM	NM	NM
		Sr-90	180 ± 20	< 0.15	70 ± 790	NM
		Pu-238	9.3 ± 1.7	0.35 ± 0.08	13 ± 18	NM
		Pu-239	14.7 ± 2.3	1.4 ± 0.2	16 ± 2.0	NM
		U-234	32 ± 4	1.00 ± 0.13	NM	NM
		U-238	32 ± 4	1.00 ± 0.13	NM	NM

Table D.10 (Continued)

Site	Date	Analyses	EPA Radionuclide Concentration Vegetation pCi/kg fresh	 Soil pCi/kg dry	SRP Radionuclide Concentration Vegetation pCi/kg fresh$^{(c)}$	 Soil pCi/kg dry
11	12/16/82	Be-7	3,400 ± 700	< 0.2	5,800 ± 8,400	< 0.13
		K-40	2,100 ± 900	2.0 ± 0.4	1,900 ± 920	1.3 ± 1.2
(Bkgnd)$^{(b)}$		Cs-137	130 ± 50	1.79 ± 0.07	410 ± 800	2.2 ± 0.15
		C-14$^{(a)}$	17.7 ± 1.4	NM	NM	NM
		Sr-90	490 ± 50	< 0.22	230 ± 740	NM
		Pu-238	< 0.7	< 0.04	3.6 ± 1.6	NM
		Pu-239	0.7 ± 0.5	< 0.04	4.4 ± 1.5	NM
		U-234	13 + 2	0.45 ± 0.12	NM	NM
		U-238	12 ± 2	0.21 ± 0.07	NM	NM

Notes:
1) See Figure 3.3 for site locations.
2) Tritium concentrations are listed in Table 4.2.
3) NM - Not measured.
a) Concentrations of C-14 are presented as dpm/g Carbon.
b) Background site for airborne effluents during collection periods.
c) Results not comparable; SRP analyses were based on analysis of dried samples, whereas EPA analyses were based on wet weight samples. SRP had only 20 grams of sample for analysis, therefore, there are large counting errors involved.

Table D.11 Radionuclide concentrations measured in foods collected near the Savannah River Plant

Food Sample	Site(a)	Collection Date	Analyses(c)	EPA Concentration, pCi/kg or liter	SRP Concentration, pCi/kg or liter
Collards	12	12/15/82	K-40	3,900 ± 300	2,800 ± 170
(pCi/kg)			Cs-137	< 30	< 98
			C-14(b)	16.5 ± 1.3	NM(e)
			Sr-90	99 ± 14	120 ± 60
			Pu-238/239	< 0.70	< 0.8
			U-234	0.4 ± 0.2	NM
			U-238	0.5 ± 0.2	NM
Collards	13	12/15/82	K-40	5,400 ± 400	5,300 ± 200
(pCi/kg)			Cs-137	< 30	< 98
			C-14(b)	16.7 ± 1.3	NM
			Sr-90	190 ± 17	170 ± 60
			Pu-238/239	< 0.70	< 0.8
			U-234	NR(d)	NM
			U-238	0.8 ± 0.04	NM
Milk	14	12/15/82	K-40	1,200 ± 200	1,500 ± 140
(pCi/l)			Cs-137	< 10	< 24
			Sr-90	1.8 ± 0.7	1.0 ± 0.8
			Pu-238/239	< 0.7	NM

Table D.11 (Continued)

Food Sample	Site[a]	Collection Date	Analyses[c]	EPA Concentration, pCi/kg or liter	SRP Concentration, pCi/kg or liter
Beef	15	12/16/82	K-40	2,300 ± 200	1,470 ± 420
(pCi/kg)			Cs-137	17 ± 7	0 ± 30
			C-14[b]	18.7 ± 1.5	NM
			Sr-90	5.5 ± 1.2	60 + 70
			Pu-238/239	< 0.3	NM

(a) See Figure 4.1 for site locations.
(b) Concentrations of C-14 are presented as dpm/g Carbon.
(c) Tritium concentrations are given in Table 4.2.
(d) NR - Not reported.
(e) NM - Not measured.